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INDIAN AGRICULTURAL
RESEARCH INSTITUTE, NEW DELHI

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THE
**SOUTH AFRICAN JOURNAL
OF SCIENCE**
VOLUME XXXIX
BEING THE
R E P O R T
OF THE
FORTIETH ANNUAL MEETING
OF THE
SOUTH AFRICAN ASSOCIATION
FOR THE
ADVANCEMENT OF SCIENCE

JOHANNESBURG

1942

29th June to 1st July.

**JOHANNESBURG:
PUBLISHED BY THE ASSOCIATION
and**

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1943.

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for the Advancement of Science**
P.O. Box 6894, Johannesburg.

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(Note.—Academic qualifications, etc., are not indispensable.)

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3. Profession or Occupation

4. Full Postal Address

5. Signature

6. Proposed by ‡

Date

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Certain back numbers of the Journal are now obtainable from the Hon. Librarian, University, Milner Park, Johannesburg, at a reduced rate.

Candidates resident in the Witwatersrand (Randfontein to Springs) should add the sum of £1 1s. for membership of the Associated Scientific and Technical Societies of South Africa.

† Cheques, etc., should be crossed and made payable to the Assistant General Secretary, South African Association for the Advancement of Science, and 6d. should be added to country cheques to cover exchange.

‡ In this respect the Assistant General Secretaries will be prepared to assist applicants.

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**SOUTH AFRICAN ASSOCIATION FOR THE
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JANUARY, 1948.

Vol. XXXIX

EDITORIAL NOTE.

Volume 39 of the JOURNAL is somewhat smaller than any of its recent predecessors, owing to restrictions on the use of paper consequent upon a reduction of supplies. This has made it necessary to reduce the length of papers, and to record some contributions in abstract or in title only.

In accordance with the recent practice of the Association for a symposium on some subject of national importance to be held in conjunction with the annual congress, a symposium on "Science and Post-War Reconstruction" was organized by Professor John Phillips, our Honorary Editor of Publications, Mr. Jas. Gray and Dr. J. B. Robertson: the addresses delivered by the principal authorities on various aspects of the subject, together with contributions from General Smuts and Mr. J. H. Hofmeyr are included in this volume.

The attention of contributors is drawn to the request made, in the circular sent to members before the Annual General Meeting, for papers dealing with new and original work, and for very careful reading of typescripts before submission, in order to avoid, as far as possible, alterations in the proofs.

I have to thank many authors for the prompt return of their proofs as requested, and for their kind co-operation in any necessary abridgment of their papers.



Honorary Associate Editor.

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PRESIDENTS OF THE ASSOCIATION
FROM ITS FOUNDATION.

- Sir DAVID GILL, K.C.B., LL.D., F.R.S., F.R.S.E., Cape Town, April 27, 1903.
Sir CHARLES METCALFE, Bart., M.I.C.E., Johannesburg, April 4, 1904.
THEODORE REUNERT, D.Litt., M.I.C.E., M.I.M.E., Johannesburg, August 28, 1905.
GARDNER F. WILLIAMS, M.A., Kimberley, July 9, 1906.
JAMES HYSLOP, D.S.O., M.B., C.M., Durban, July 16, 1907.
H.E. Hon. Sir WALTER HELY-HUTCHINSON, G.C.M.G., LL.D., Grahamstown, July 6, 1908.
H.E. Sir HAMILTON GOOLD-ADAMS, G.C.M.G., C.B., Bloemfontein, Sept. 27, 1909.
Sir THOMAS MUIR, C.M.G., M.A., D.Sc., LL.D., F.R.S., F.R.S.E., Cape Town, October 31, 1910.
Professor PAUL DANIEL HAHN, M.A., Ph.D., Bulawayo, July 3, 1911.
Sir ARNOLD THEILER, C.M.G., D.Sc., Port Elizabeth, July 1, 1912.
ALEXANDER W. ROBERTS, D.Sc., F.R.A.S., F.R.S.E., Lourenco Marques, July 7, 1913.
Professor RUDOLPH MARLOTH, M.A., Ph.D., Kimberley, July 6, 1914.
ROBERT T. A. INNES, D.Sc., F.R.A.S., F.R.S.E., Pretoria, July 5, 1915.
Professor LAWRENCE CRAWFORD, M.A., D.Sc., F.R.S.E., Maritzburg, July 3, 1916.
Professor JOHN ORR, O.B.E., LL.D., B.Sc., M.I.C.E., M.I.Mech.E., Stellenbosch, July 2, 1917.
CHARLES F. JURITZ, M.A., D.Sc., F.I.C., Johannesburg, July 8, 1918.
Rev. WILLIAM FLINT, D.D., Kingwilliamstown, July 7, 1919.
ILLTYD BULLER POLE EVANS, C.M.G., M.A., D.Sc., F.L.S., Bulawayo, July 14, 1920.
Professor J. E. DUERDEN, M.Sc., Ph.D., A.R.C.S., Durban, July 11, 1921.
ARTHUR W. ROGERS, Sc.D., M.A., F.R.S., Lourenco Marques, July 10, 1922.
Professor J. D. F. GILCHRIST, M.A., D.Sc., Ph.D., Bloemfontein, July 9, 1923.
Professor J. A. WILKINSON, M.A., F.C.S., M.I.Chem.E., Cape Town, July 7, 1924.
Field Marshal the Rt. Hon. J. C. SMUTS, K.C., P.C., C.H., LL.D., M.L.A., Oudtshoorn, July 6, 1925.
E. T. MELLOR, D.Sc., F.G.S., M.I.M.M., Pretoria, July 5, 1926.
Professor H. B. FANTHAM, M.A., D.Sc., Salisbury, June 29, 1927.
Sir CARRUTHERS BEATTIE, D.Sc., LL.D., Kimberley, June 20, 1928.
Hon. J. H. HOFMEYR, M.A., D.Sc., Johannesburg-Cape Town, July 22, 1929.
H. E. WOOD, D.Sc., F.R.A.S., Caledon, July 7, 1930.
Professor J. W. BEWIS, M.A., D.Sc., Grahamstown, July 6, 1931.
Professor P. J. DU TOIT, B.A., D.Phil., Dr. Med. Vet., D.Sc., Durban, July 4, 1932.
ROBERT BROOME, M.D., C.M., D.Sc., F.R.S., Barberton, July 3, 1933.
A. L. DU TOIT, B.A., D.Sc., F.G.S., Port Elizabeth, July 2, 1934.
Professor M. M. RINPL, Ing.D., Paarl, July 1, 1935.
H.E. the Rt. Hon. the EARL OF CLARENDON, P.C., G.C.M.G., Governor-General of the Union of South Africa, Johannesburg, October 5, 1936.
Lt.-Col. C. GRAHAM BOTHA, V.D., M.A., Windhoek, July 5, 1937.
Professor L. F. MAINGAARD, M.A., D.Lit., Maritzburg, July 4, 1938.
Professor G. H. STANLEY, D.Sc., A.R.S.M., M.I.M.M., F.I.C., East London, July 8, 1939.
Professor C. G. S. DE VILLIERS, M.A., Ph.D., Johannesburg, July 1, 1940.
JAMES GRAY, F.I.C., Johannesburg, June 30, 1941.
E. PERCY PHILLIPS, M.A., D.Sc., F.L.S., Johannesburg, June 29, 1942.

PROCEEDINGS OF THE FORTIETH ANNUAL GENERAL MEETING OF MEMBERS HELD AT KELVIN HOUSE, JOHANNESBURG, ON TUESDAY, 30th JUNE, 1942, AT 12 NOON.

PRESENT: Dr. E. Percy Phillips (President) (in the Chair), Professor A. W. Bayer, Dr. Maria G. Breyer, Mr. J. Collie, Dr. A. L. du Toit, Dr. R. A. Dyer, Mr. James Gray, Mr. T. D. Hall, Mr. G. Ingham, Mr. H. A. G. Jeffreys, Mrs. L. Jeffreys, Dr. R. J. A. Jordan, Dr. F. E. T. Krause, Dr. M. S. J. Ledebuur, Professor L. F. Maingard, Mr. D. B. D. Meredith, Dr. M. G. Mes, Professor John Orr, Mr. F. R. Paver, Professor John Phillips, Dr. A. Pijper, Dr. J. I. Quin, Mr. J. Lyall Scutte, Professor G. H. Stanley, Miss E. E. Wijers, Dr. H. E. Wood (Acting Honorary General Secretary), Mr. S. B. Asher and Mr. I. M. Sinclair (for Assistant General Secretaries).

APOLOGIES.—Mr. P. R. O. Bally, Professor A. P. G. Goossens, Dr. E. J. Hamlin, Mr. R. H. Harriss, Mr. A. J. Limebeer, Professor H. H. Paine and Mrs. A. E. Thomas.

1. MINUTES: The Minutes of the Thirty-Ninth Annual General Meeting, held at Johannesburg on the 1st July, 1941, and printed on pages iii to v of the Report of the Johannesburg Session (Volume XXXVIII of the Journal), were confirmed.

2. ANNUAL REPORT OF COUNCIL.—The Annual Report of the Council for the year ended 30th June, 1942, having been duly suspended on the Notice Board, was taken as read and adopted.

3. REPORT OF THE HONORARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS.—The Honorary General Treasurer's Report and the Statement of Accounts for the year ended 31st May, 1942, having been duly displayed on the Notice Board, were taken as read and adopted.

4. ELECTION OF GENERAL OFFICERS.—The following were elected as General Officers for the year 1942-1943:—

President: Dr. A. Pijper.

Vice-Presidents: Mr. R. Craib.

Colonel J. G. Rose.

Professor S. F. Bush.

Dr. E. C. N. Hoopen.

Honorary General Secretaries: Dr. C. F. Juritz and Professor H. H. Paine.

Honorary Treasurer: Mr. James Gray.

Honorary Editor: Professor John Phillips.

Honorary Associate Editor: Mr. S. B. Asher.

Honorary Librarian: Mr. P. Freer.

Dr. A. Pijper expressed his appreciation of the honour conferred on him in his election as President for the year 1942-1943:—

5. ELECTION OF COUNCIL MEMBERS.—The following were elected as Council Members for the year 1942-1943.

Transvaal: Mr. S. B. Asher, Mr. T. D. Hall, Dr. E. J. Hamlin, Mr. R. H. Harriss, Professor P. R. Kirby, Mr. A. J. Limebeer, Professor I. D. MacCrone, Professor L. F. Maingard, Professor John Orr, Mr. F. R. Paver, Dr. J. B. Robertson, Professor G. H. Stanley, Dr. L. H. Wells, Dr. G. de Kock, Dr. P. J. du Toit, Dr. R. A. Dyer, Dr. F. E. T. Krause, Dr. M. G. Mes, Dr. E. M. Robinson and Professor A. P. G. Goossens.

Cape of Good Hope: Dr. L. D. Boonstra, Colonel C. Graham Botha, Dr. A. L. du Toit, Mr. G. W. Lyon, Dr. B. de C. Marchand, Dr. S. H. Skaife, Mr. F. J. S. Anders, Professor C. G. S. de Villiers, Dr. P. W. Laidler, Mr. J. Hewitt, Mr. J. H. Power, Dr. M. Boehmke and Dr. C. von Bonde.

Orange Free State: Mr. F. W. Storey.

Natal: Mr. E. C. Chubb, Mr. E. B. Dunkerton, Mr. J. F. Schofield, Professor A. W. Bayer and Dr. R. F. Lawrence.

Southern Rhodesia: Mr. H. B. Maufe.

6. AMENDMENTS TO THE CONSTITUTION.—Mr. James Gray moved the adoption of the following amendments to the Constitution, which amendments had been approved by the Council in accordance with the provisions of Section 40 of the Constitution:—

Section 13: Delete “Every Life Member . . .” to end of Section and substitute:

“By the payment of a sum of £30 a new member may become a Life Member and be exempt from any further subscriptions.”

Section 15: Delete “An ordinary member . . .” to end of Section and substitute:—

“Ordinary members may become Life Members by the payment of the initial subscription for Life Membership (i.e. £30) reduced by £1 for every year of ordinary membership. Ordinary members who have paid their subscriptions for thirty years shall become Life Members and be exempt from payment of further subscriptions.”

Mr. Gray reported that the Cape Centre had asked that the views of the Centre as expressed in the following resolution passed at a meeting held on the 8th May, 1942, be placed before members:—

“The Meeting still regarded the proposed fee of £30 as too high and as disproportionate to the Life Membership fees of other similar institutions.”

Dr. F. E. T Krause seconded the motion of Mr. Gray, after which the amendments to the Constitution, as shown above, were carried by the Meeting.

7. SUBSCRIPTIONS OF ASSOCIATE AND STUDENT MEMBERS.—The action taken by the Council in making the subscriptions of Associate Members for the 1942 Annual Meeting ten shillings and of Student Members five shillings was confirmed, it being noted that this action had been taken as a result of the curtailment of the Meeting to three days.

8. LEGISLATION AFFECTING ENGINEERING AND SCIENTIFIC PROFESSIONS.—It was agreed to support the following resolution which had been approved by the Witwatersrand Local Centre and had been submitted to the Government by the Associated Scientific and Technical Societies of South Africa, and to advise the Controlling Executive of the Associated Scientific and Technical Societies of South Africa accordingly:—

“The Controlling Executive of The Associated Scientific and Technical Societies of South Africa, representing the undermentioned bodies, views with apprehension the present tendency of the Government to rush legislation through Parliament affecting the Engineering

and certain Scientific professions without giving representative bodies of these professions sufficient opportunity to express their views on such legislation prior to decisions being taken:—

- The Chemical, Metallurgical and Mining Society of South Africa.
- The Geological Society of South Africa.
- The Institute of Land Surveyors of the Transvaal.
- The Institute of South African Architects, the Transvaal Provincial Institute.
- The Institution of Certificated Engineers, South Africa.
- The South African Association for the Advancement of Science (Witwatersrand Branch).
- The South African Association of Assayers.
- The South African Chemical Institute.
- The South African Institution of Engineers.
- The South African Institute of Electrical Engineers.
- The Natal Institute of Engineers (Affiliated Society)."

9. ANNUAL MEETING—1943.—In view of the international situation, it was agreed that the Council have power to decide the venue of the 1943 Annual Meeting, or should it be deemed expedient to do so, to suspend the holding of an Annual Meeting next year.

10. VOTES OF THANKS.—On the proposal of Dr. A. Pijper, a unanimous vote of thanks was accorded the Associated Scientific and Technical Societies of South Africa for providing the necessary accommodation for the holding of the Annual Meeting in Kelvin House, to the Honorary Auditors, Messrs. Alex. Aiken and Carter, for their services in carrying out the audit for the year 1941-1942, and to the Press for their services in reporting the proceedings of the Annual Meeting.

Mr. James Gray proposed a hearty vote of thanks to the President for the able manner in which he had conducted the Meeting and for his services to the Association during his term of office, this vote of thanks being received with acclamation.

The President, in acknowledging Mr. Gray's kind remarks, congratulated the Association on its choice of Dr. A. Pijper as President for the year 1942-1943.

11. GREETINGS.—The President reported that greetings had been received from Dr. T. N. Leslie, who unfortunately was unable to be present at the Meeting on account of ill health.

It was agreed that a letter of appreciation of his good wishes be sent to Dr. Leslie.

Telegrams of greeting from the Durban Centre and from Professor H. H. Paine, who was engaged on military duties, were read and noted with appreciation.

12. APPRECIATION OF SERVICES OF HONORARY ASSOCIATE EDITOR.—Professor John Phillips stated that he wished to take this opportunity of expressing his appreciation of the excellent work Mr. S. B. Asher had done during the past year as Honorary Associate Editor, especially as war duties had precluded him from giving Mr. Asher the assistance which should have been afforded him.

This concluded the business and the meeting terminated at **12.26 p.m.**

**REPORT OF COUNCIL FOR THE YEAR ENDING
30th JUNE, 1942.**

1. **OBITUARY.**—Your Council reports with regret the deaths of the following members: Dr. Alexander Aiken (Trustee of the Endowment Fund), the Reverend R. Balmforth, the Reverend S. S. Dornan, Dr. E. E. Galpin, Dr. P. Gutsche, Mr. A. C. McColm, Mr. H. Rainey, Dr. G. Rattnay, and Mr. C. E. Z. Watermeyer.

2. **MEMBERSHIP.**—Since the last Report thirty-one members have joined the Association, nine have died, and twelve have resigned.

The following table shows the geographical distribution of membership as at the 30th June, 1942:

Transvaal	320
Cape of Good Hope Province	155
Natal	75
Orange Free State	19
Southern and Northern Rhodesia	10
South West Africa	2
Mocambique	2
Abroad	23
	606

3. **THE JOURNAL.**—Volume XXXVIII of the South African Journal of Science, comprising the Report of the Johannesburg Meeting, was placed in the hands of members in April, 1942. It consisted of 431 pages and contained 28 papers (in full or in abstract) in addition to the Presidential Addresses.

4. **QUARTERLY BULLETINS.**—Three Bulletins have been issued during the year under review, in October, 1941, April, 1942, and June, 1942, respectively.

5. **THE SOUTH AFRICA MEDAL AND GRANT.**—No nomination was received.

6. **THE BRITISH ASSOCIATION MEDAL.**—No recommendation was made.

7. **DONATIONS.**—The thanks of the Association are due to the Honourable the Minister of Finance and of Education for a grant of £250 towards the expenses of the publication of the Journal and to the Johannesburg Municipality for a grant of £100.

8. **TRUSTEE OF THE ENDOWMENT FUND.**—Professor John Orr was appointed vice the late Dr. Alex. Aiken.

9. **FOUNDATION FOR THE STUDY OF CYCLES.**—A request was received from the Foundation for the Study of Cycles, Washington, U.S.A., through the National Research Council and Board and the Associated Scientific and Technical Societies of South Africa, for a list of Scientists in the Union who have contributed to the fund of knowledge in respect of rhythmic or periodic behaviour in any field of Science. A list of 14 names (with addresses) was forwarded.

10. **ANNUAL MEETING, 1942.**—In accordance with the instructions given at the Annual General Meeting in 1941, the Council arranged for a short Annual Meeting of the Association to be held in Johannesburg at the end of June, 1942, the programme to be similar to that followed in 1941 and to consist mainly of Presidential Addresses. This year a Symposium on "Science and Post-War Reconstruction" has been arranged for the third day of the Session, to be presided over by the Honourable J. H. Hofmeyr, Past President of the Association.

11. THE NEW COUNCIL.—On the basis of membership provided in the Constitution, Section 22, the numbers of members of Council assigned for the representation of each Centre during the ensuing year should be distributed as follows:—

<i>Transvaal:</i>							
Witwatersrand	...	...	...	...	...	13	
Pretoria	...	...	...	...	...	6	
Outside	...	...	...	...	...	1	
<i>Cape of Good Hope Province:</i>							
Cape Peninsula and Outside	...	...	...	...	...	6	
Stellenbosch and District	...	...	...	...	...	2	
East London and Port Elizabeth	...	...	...	...	...	1	
Grahamstown, Kingwilliamstown and District	...	...	...	...	...	1	
Kimberley	...	...	...	...	...	1	
Oudtshoorn	...	...	...	...	...	1	
Outside	...	...	...	...	...	1	
<i>Natal:</i>							
Durban	...	...	...	...	...	3	
Pietermaritzburg and Outside Districts	...	...	...	...	...	2	
<i>Orange Free State:</i>							
Bloemfontein	...	...	...	...	...	1	
<i>Southern Rhodesia</i>	...	...	...	...	...	1	
Total ..						40	

12. HONORARY AUDITORS.—Messrs. Alex Aiken and Carter have again acted as Honorary Auditors to the Association for the year 1941-1942, and deserve the thanks of the Association.

13. SECRETARIAT.—The Council wishes to express its appreciation of the services of the Associated Scientific and Technical Societies of South Africa who have continued to carry out the secretarial work of the Association during the year, and especially of the valuable assistance rendered by Mr. A. J. Adams and Mr. I. M. Sinclair.

**REPORT OF THE HONORARY GENERAL TREASURER FOR
THE YEAR ENDED 31st MAY, 1942.**

During the year the Association has maintained a satisfactory financial position and the excess of revenue over expenditure was £204. The profit last year was £363. The amount received in arrear subscriptions is about £200 less than last year but it will be remembered that the position regarding arrear subscriptions was closely examined then and those in arrears beyond the normal period allowed were notified that failing payment their membership would cease and consequently collections were greater than normal.

Other items of revenue and expenditure call for no special comment, showing very little variation from previous statements.

It is gratifying to report in these abnormal times that the financial position of the Association is sound.

JAS. GRAY,
Honorary General Treasurer.

**THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
BALANCE SHEET AT 31ST MAY, 1942.**

We have examined the books and vouchers of the South African Association for the Advancement of Science for the year ended ~~May~~¹⁹⁴², and certify that in our opinion the above Balance Sheet correctly sets forth the position of the Association at the ~~31st~~^{30th} May, 1942, according to the best of our information and the explanations given by the books.

ALEX. AIKEN & CARTER,
Auditors

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1942.

Dr.	Cr.
To Secretarial Fees	£ s. d.
,, Journal Expenses	709 6 11
,, Less Government Grant	£250 0 0
,, Johannesburg Municipal Grant	100 0 0
Sales, Reproofs & Advertisements	238 10 8
	<u>688 10 8</u>
" Stationery and Printing	120 16 3
" Postages	79 8 3
" Expenses—Annual Meeting	21 5 5
" 1941 (Balance)	3 0 0
" Sundry General Expenses	12 12 1
" Grants to Local Centres under Rule 35—	
,, Witwatersrand	21 3 0
,, Cape Province	10 5 6
,, Natal	7 19 0
" Depreciation on Office Furniture	<u>39 7 6</u>
" Pension—H. A. G. Jeffreys	10 12 6
" Balance, being Excess of Revenue over Expenditure for the year ended 31st May, 1942	90 0 0
	<u>204 0 7</u>
	<u>£761 2 7</u>
ACCOUNTS.	
	x.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
ENDOWMENT FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1942.

	£	s.	d.	£	s.	d.
To Interest, as per contra, transferred to General Fund	130	10	3	130	10	3
" Life Membership Subscriptions ..	30	0	0	30	0	0
,, Balance transferred to Accumulated Funds	30	0	0			
	£160	10	3			
By Interest received during the year ..	..	..	..
" Life Membership Subscriptions ..	..	..	..
	£160	10	3			

BALANCE SHEET AT 31st MAY, 1942.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

ACCOUNT FOR THE YEAR ENDED 31st MAY, 1942.

Dr.	REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR			£	s.	d.
		£	s.	d.		
To Balance transferred to Library Binding and Equipment Account	74 17 6					
		<u>74 17 6</u>				
				By Interest received during the year ...		
					74 17 6	
						<u>£74 17 6</u>

BALANCE SHEET AT 31st MAY, 1842.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
SOUTH AFRICA MEDAL FUND.

Dr.	REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1942.	Cr.
To Expenses incurred during the year	£ 4 0 0	By Interest received during the year
, , Balance transferred to Accumulated Funds	52 12 10	56 12 10
	<hr/> £56 12 10	<hr/> £56 12 10

BALANCE SHEET AT 31st MAY, 1942.

LIABILITIES.	ASSETS.
<i>Sundry Creditors—</i>	<i>Investments in Hands of Trustees—</i>
Expenses incurred during the Year	Fixed Deposit, South African Permanent Mutual Building and Investment Society 1,666 0 1
<i>Accumulated Funds—</i>	Post Office Savings Bank 8 9 0
Balance at 31st May, 1941	1 617 16 3
<i>Add</i> Amount transferred from Revenue and Expenditure Account	<hr/> 52 12 10
	<hr/> 1,670 9 1
	<hr/> £1,674 9 1

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
THE BRITISH ASSOCIATION MEDAL FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1942.

BR.		REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1942.		CR.	
To	Award	£	s.	d.	
		20	0	0	By Interest received during the year
					.. Balance transferred to Accumulated Funds
					£20 0 0
					£20 0 0

BALANCE SHEET AT 31st MAY, 1942.

LIABILITIES.				ASSETS	
Accumulated Funds—				Investments in Banks of Trustees—	
Balance at 31st May, 1941				£450 Union of South Africa 3½% Local Stock 1948/58	
£455	Amount transferred from Revenue and Expenditure Acco.int	3	2	6	483 10 3
					£483 10 3

**REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR
ENDED 31st MAY, 1942.**

The Association's Library is housed in the Library of the University of the Witwatersrand, Johannesburg.

HOURS OF OPENING—

Weekdays. Term: 8.30 a.m. to 6 p.m.
Vacation: 9 a.m. to 5 p.m.

Saturdays. Term: 8.30 a.m. to 12.30 p.m.
Vacation: 9 a.m. to 12.30 p.m.

EXCHANGE OF PUBLICATIONS. During the year the following names were added to the exchange mailing list:—

Academy of science of St. Louis.

Instituto de biología, Mexico.

Museum of comparative zoology, Harvard College.

North Carolina state college of agriculture and engineering.

DONATIONS. Gifts other than exchange material were received from the following:—

British museum (Natural history):

John Murray Expedition Reports. Vol. 2 nos 3-5; vol. 3 nos 2-4; vol. 5 no. 9; vol. 6 nos 1-8; vol. 7 no 1.

Catalogue of the books, mss. maps and drawings, vol. 8.

Fossil orthoptera. Text and Plates.

Guide to crystal symmetry.

Economic leaflets nos. 3 and 4.

British blood-sucking flies.

Dr. H. Husserl.

Epidemic of Naples in the 15th century.

Mr. B. Narbeth.

South African journal of science. v. 13-35, 1916-38.

Royal Observatory, Greenwich.

Catalogue of 20,554 stars in the Cape astrographic zone.

Southern Rhodesia. Legislative assembly.

Parliamentary papers 1940.

Mr. C. T. Van Rooyen.

South African Journal of Science. v. 22-32, 34-35, 1925-38.

JOURNAL. Volumes of the *Journal* were presented to the following libraries to help complete their own sets:—

Academy of science of S. Louis.

College of agriculture, Cedara.

Division of forestry, Pretoria.

Royal society of Edinburgh.

In response to an appeal from the Royal Empire Society, the greater part of whose library was destroyed by enemy action, a letter was sent advising the Librarian that as complete a set of the *Journal* as is available would be reserved for them to be sent after the war. In addition, part sets and back volumes were supplied on orders from the Cape explosive works; A. Melignon, Belgian Congo, and the F. W. Faxon Co., New York.

STOCK. Owing to the extension of the war zone a large number of titles have disappeared from the current list, but 180 titles are still being received. The Library now contains about 3,500 volumes.

ACCESSIONS TO SERIAL PUBLICATIONS, 1941/42.

- Agricoltura Libica. 7-9, 1938-40 incomp.
- Canada. Geological survey. Paper. 39, 1940+
- Association des chimistes. Bulletin. 57, 1940+
- Kirkwood observatory. Publications. 1, 1939+
- New York academy of sciences. Transacs. 1, 1938+
- North Carolina. Engineering experiment station. Bulletin. 23, 1942+
- Société scientifique de Bretagne. Bulletin. 13-15, 1936-38.
- Thai science bulletin. 1-3, 1939-41 incomp.

For a Catalogue of serial publications in the Library, and Supplement, see this Journal, vol. 30, p. xxv-xxix and vol. 34 pp. xxxiv-xxxvii. Subsequent accessions are listed in the Annual Report.

P. FREER.

Hon. Librarian.

University of the Witwatersrand,
Johannesburg.
9th June, 1942.

**SOUTH AFRICAN CURRENT SCIENTIFIC AND TECHNICAL
PERIODICALS RECEIVED BY THE LIBRARY OF THE
ASSOCIATIONS.**

- Astronomical Society of South Africa, Journal
- Assoc. Scientific and Technical Societies of South Africa, Proceedings.
- Bloemfontein, Nasionale Museum Navorsinge.
- Boerdryk in Suid-Afrika.
- Chemical, Metallurgical and Mining Society of South Africa, Journal.
- Geological Society of South Africa, Transactions and Proceedings.
- Natal Museum, Annals.
- Onderstepoort Journal.
- Rhodesia Agricultural Journal.
- Rhodesia Scientific Association, Proceedings.
- Royal Society of South Africa, Transactions.
- South African Chemical Institute, Journal.
- " " Engineering.
- " " Institute of Engineers, Journal.
- " " Institute of Electrical Engineers, Transactions.
- " " Journal of Science.
- " " Museum, Annals
- " " Sugar Journal.
- Transvaal Museum, Annals.
- Farming in South Africa.
- Union Observatory, Circulars.

Periodicals may be borrowed by Members from the Library of the Association.

In Memoriam.

GEORGE RATTRAY, M.A., D.Sc., F.R.G.S.

Dr. George Rattray, who died in May, 1941, at the age of 68, was an Aberdeenshire man and was educated at Aberdeen University, where he graduated M.A., B.Sc. After teaching for a while at Dumfries Academy, he came to South Africa and taught for some years, first at Wellington and afterwards at Graaff-Reinet. In 1904 he was appointed headmaster of the East London Boys' High School. Under him the school made such progress that eventually new buildings became necessary and the fine educational block known as Selborne College was erected. (It was in this block that the South African Association for the Advancement of Science held its meetings in 1939.) After 26 years of excellent service, Dr. Rattray, for health reasons, retired in 1930 before reaching the age limit.

He was a man of wide interests, but specialised in Botany, in which he was a recognised authority. For his monograph on the Cycads of South Africa he received from his university the degree of Doctor of Science. Until the last few years of his life, when he was laid aside by paralysis, he spent most of his spare time in the veld, collecting specimens and studying the flora generally. His researches into the Cycadaceae took him far afield in South Africa and in this work he was associated with the late Professor H. H. Pearson of the University of Cape Town, and later with Professor Chamberlain, of Chicago University.

He was mainly responsible for establishing the manner in which various species of *Encephalartos* are pollinated —by the agency of a small weevil. He found that a large percentage of the seeds were infested by the larva of this insect. The next step was to find it on the male cone, and this was an easy matter; for investigation showed that, attracted by the strong odour of the male cone when it is ripe, hundreds of the weevils visited it to eat the pollen, some of which adhered to their legs and bodies. Having fed, they flew off to the female cone for the purpose of depositing their eggs inside it, and in the process rubbed off some of the adhering pollen on to the ovules. This was an expensive method of securing fertile seeds, for the young weevil devours all the seed except the husk. Rattray found, however, that a few seeds were not infested and developed normally. In an actual case observed, out of about 150 seeds, the produce of a single female cone, only 35 were found to be fertile.

But Rattray's interests were not confined to plants; he was always a keen observer of animal life. During one of his visits to the forests of Hogsback in the Amatolas he discovered a tiny frog which lays its ova in a hole in the ground remote from water. Some moisture is needed for the hatching of the embryos, but if placed in water they drown. The frog, which has no webs on its feet or discs on its toes, was named after its discoverer, *Anhydrophryne rattrayi*.

As a schoolmaster Rattray was an admirable teacher, disciplinarian and organiser, and those gifts accounted for his success in his profession. Out of school his genial manner, his keen sense of humour, his conversational gifts and the wide variety of his interests made him a charming companion whether in the study or in the field.

B. H. MODDOS.

SOUTH AFRICAN JOURNAL OF SCIENCE, Vol. XXXIX, pp 1-20.
January, 1943.

THE ADVANCEMENT OF SCIENCE

BY

DR. E. P. PHILLIPS,

Chief, Division of Botany and Plant Pathology.

PRESIDENT.

Presidential Address delivered 29th June, 1942.

The choice of a subject for a Presidential Address naturally requires some thought; it should not be too technical and should have an appeal to the varied interests in an organisation such as the South African Association for the Advancement of Science. For many years past the historical background of science, thought, and customs generally have had a fascination for me. I believe that such historical studies have much to teach us in understanding why we think and act as we do to-day. I have therefore chosen as the title of my address "The Advancement of Science" and shall attempt to present to you the advancement of science not as a series of individual achievements, but as a continuous series of evolutionary changes, i.e., I shall attempt to draw a parallel between the advancement of science and evolution in the organic world. Generally there is a tendency to link together a great scientific discovery with an individual name; this may be convenient but it does not give us a true picture of the advancement of science. The foundations of science were, I believe, laid down in prehistoric times, and throughout the ages brick after brick has been added until the present edifice, as we know it, has come into being. There is also a tendency to accept the practical applications of science as synonymous with science itself and often such practical applications are accorded more importance than is accorded to pure scientific research.

A study of the history of science shows that advancement in one branch may be delayed until some fundamental discovery is made in another branch. For example, knowledge about the physiology of plants could not proceed until the chemist gave us the composition of the atmosphere; the astronomer, before he could obtain any knowledge of the composition of the sun and stars, had to await the invention of the spectroscope; Pasteur's work in one scientific field led

to research in many other scientific fields. Such examples could be multiplied many times but they suffice as examples to illustrate the dependence of one branch of science on another. A survey of the history of science makes us realize that science is international; it knows no political boundaries or creeds, and men of all nationalities have added their quota to the sum total of our present knowledge. The only limits imposed, are that scientific discoveries must stand the test when placed in the balance of the general knowledge prevalent at the time. The history of science also impresses upon us how the influence of science and the inventions arising from scientific discoveries, have moulded our present civilization. In this connection I am more than ever convinced that a part of the education of every science student should include a course in the general historical background of science—not so much the history of any particular science, but of science as a whole.

The Encyclopaedia Britannica defines science as "a word which in its broadest sense is synonymous with learning and knowledge," but states that general modern convention accepts the definition as "ordered knowledge of natural phenomena and the relation between them." When using the word science, I have the latter definition in mind.

It is a serious mistake to think that all scientific discoveries of note and the practical applications flowing from them, date from the period of modern science. The average layman of this century who is surrounded by the technical applications of science is apt to assume that all scientific discoveries and inventions are of recent growth, while I am sure that many workers in science probably do not fully appreciate how important were some of the discoveries made thousands of years ago which we accept to-day, without question, as part and parcel of our daily experience. When we go back to pre-historic times, we can only speculate on the extent of man's knowledge of natural phenomena. Our definite knowledge of man begins with the period in which he left us written records, but thousands of years elapsed before that stage was reached and within that period discoveries of a fundamental nature must have been made, without which, civilization would have been impossible. The man who discovered the use of fire made no less a great discovery than the man who discovered electricity; the man who found that seeds could be sown and the fruits reaped, advanced human knowledge no whit less than the modern agriculturist who preaches the rotation of crops; the first

man to fashion a stone implement for offensive and defensive purposes, was an inventor relatively as great as any modern technician who designs modern arms. We may also assume that primitive man made deductions from isolated facts of natural phenomena. For example, the advent of the seasons, the growth of herbs, the production of fruits, the birth of a child, the coming and going of their food animals, the death of an individual were at first isolated phenomena. When man connected the death of an individual with the eating of a certain fruit or herb at a particular time of the year, he made a profound scientific discovery—he discovered the relationship between different phenomena, which is science. It must be conceded that natural phenomena which impinged so closely on man's daily life—indeed on his very existence—could not have passed unnoticed. The point I wish to make, is that the roots of science are embedded in the racial history of man. Man and science are inseparable, as, early in his development he prepared the ground on which science is built, i.e. the observation of facts of natural phenomena. That many of his deductions were incorrect is not surprising as he was not in a position to distinguish between appearances and realities. Many such wrong deductions persisted for thousands of years as e.g. the belief that the sun revolves round the earth. It was not until late in the period of civilization that the empirical knowledge gained by man through experience was classified and correlated and so became scientific knowledge. Empirical knowledge gained through experience and experiment is, however, not science; science is an organised body of facts which have been co-ordinated and generalized into a system. Men later formulated hypotheses which, if not upset by all the known facts, became scientific laws. The scientific method of controlled experiments and observations, on which modern science is based, is of relatively recent origin. The great Italian Leonardo da Vinci wrote about five hundred years ago as follows: "Experiment is the interpreter of nature. Experiments never deceive. It is our judgment which sometimes deceives itself because it expects results which experiment refuses. We must consult experiment, varying the circumstances, until we have deduced general rules, for experiment alone can furnish reliable rules." Modern science has been built up on the experimental method, controlled and varied, until the correct answer is given.

I submit that modern science has gradually evolved over a period of almost half a million years, from the first observed

facts of nature made by primitive man. It has been a slow evolutionary process, but the results as we know them to-day, constitute a triumph to man's intellect. What the future of science will be we cannot foresee. I would even suggest that the advancement of science should be regarded as a specific function of the animal we call man, and that it is but an expression of his insatiable curiosity to understand nature of which he himself forms a part.

It is not my intention to trace in any detail the history of science in ancient times but merely to show, by citing a few examples, that scientific enquiry had very early reached a high degree of development. Much of it may appear crude to us, but it is no more crude than many of the theories held even as late as the eighteenth century. We cannot, however, obtain a complete picture of the advancement of science if we do not include a study of the state of knowledge in the ancient periods.

In the old civilizations of which we have some definite knowledge, we find a high state of complexity and efficiency. The outstanding accomplishments that draw our first attention, are the remarkable engineering achievements underlying which were sound scientific principles. These, to the general reader, somewhat overshadow the state of scientific knowledge that then existed. The Chinese, about the year 3,000 B.C., discovered the scientific principle underlying the use of the wheel, and long before the Christian era they divided the year into $365\frac{1}{4}$ days and added an extra day every fourth year. The Maya of Central America and Southern Mexico had a solar year of $365 +$ days and the Egyptians, about the year 4,000 B.C., had divided the year into 365 days. In the Golden Age of Egyptian science, the study of medicine was well established and with the knowledge of the time was systematized. Babylonia, about 5,000 B.C., was well advanced in civilization; the large and well built cities and engineering in the form of complicated irrigation systems comprising hundreds of miles of canals and ditches, reached a high state of proficiency. Language had been reduced to written form, a list of the stars had been compiled and eclipses could be predicted, thus anticipating by many centuries the work of the astronomers of the sixteenth century. Horticulture was well established in Egypt and China about the year 3,000 B.C. As an art, it must have been established still earlier, so that our modern botanic gardens for the scientific study of plants which developed from the medicinal gardens of the Middle Ages, have a long

evolutionary history. A people, such as the Egyptians, who were able to conceive, plan and execute the building of such a gigantic structure as the Great Pyramid, must not only have had a knowledge of practical mathematics but must have reached a high state of mental development. The Egyptians anticipated the Suez Canal by over 3,500 years when they constructed a navigable canal one hundred miles long which connected the Nile with the Red Sea. The world's largest canal, 1,200 miles long, was commenced in China about the year 500 B.C., and a piece of construction, unequalled in the history of the human race, viz. the Great Wall of China, 2,500 miles long, was commenced in the year 240 B.C. Probably the first paved roads ever made in the world were built in Crete in the year 2,000 B.C. This was followed by the world's pioneer road makers—the Romans—who commenced the Appian Way in the year 312 B.C. and, who in the course of their rule, built more than 50,000 miles of concrete roads.

Every school child of normal intelligence is able to learn our system of notation within a comparatively short time, yet it took men thousands of years before any system of notation was invented and still thousands of years before man introduced the zero into his notation. The invention of the notation by the early Sumerians and Hindus has contributed in no small measure to the progress of human intelligence. The beginnings of chemistry, physics, zoology, metallurgy, etc., were also laid down in the period covered by the early civilizations.

From the few examples I have cited, our first impressions of the credulity and superstition of past centuries must be replaced by unbounded admiration at what was accomplished. It was the period in which many of the everyday things we use to-day had to be invented and this involved thousands of years of mental struggle. The period may perhaps be likened to the recent period in the Quaternary in organic evolution when man first appeared.

During the Greek period, scientific enquiry into all branches of knowledge became highly developed and out of this period arose the era of European science. To the Greeks must be given the credit of introducing the spirit of freedom of thought, divorced from religion, politics, or social considerations, into all their enquiries. They thus established the principle of intellectual freedom independent of authority, without which the advance of science cannot take place. It has been said of the Greeks that they had no

antiquity of knowledge and no knowledge of antiquity; this was their strength—their freedom from hampering intellectual tradition. The Greeks also taught us the value of scepticism and doubt without which science would stagnate.

There is ample evidence that the Greeks, through travel, were acquainted with the state of knowledge in other countries, more especially with that of Egypt. There is no sphere of knowledge that was not embraced within the Greek investigation and speculation, and many scientific treatises which formed the foundations of later scientific work, were written by them. The Greeks speculated on all aspects of natural phenomena; the formation of the earth and the heavens; the structure of matter, etc., and their views were tenaciously held until well into the 15th century. I must, however, refrain from giving any details of the state of knowledge that existed during the Grecian period. It will be sufficient for my purpose to cite the work on astronomy by Thales. Plato, and Hipparchus; that on geology by Xenophanes and Herodotus; the botanical work of Theophrastus and Dioscorides; the geographical work of Eratosthenes; the zoological publications of Aristotle; the medical studies of Hippocrates and that on comparative anatomy by Herophilus; and the progress made in mathematics, especially geometry, trigonometry, and algebra.

Aristotle, who is regarded by several authorities as one of the greatest minds the human race has produced, exerted a tremendous influence on the future progress of science and thought. For almost 2,000 years he was regarded as the final authority on all branches of science and his philosophy was later adopted as the official view of the Catholic Church. The influence of Aristotle and other Greek philosophers, as exercised through the Church, was undoubtedly a brake on scientific progress for a long period until the spirit of scepticism and doubt again gained control of men's minds.

After the decline of Greek culture, Europe slipped into the Dark Ages. While the light of learning and knowledge was kept burning in the monasteries the spirit of free enquiry ebbed. To doubt, to seek proof through experiment was not encouraged; authority was almost the only guide, and venturesome exploration that might upset authority was dangerous. Tyndall wrote of the Middle Ages "this era was one of intellectual servility and unquestioning acceptance of authority." Fortunately the lamp of science was kept alight by the Persians and Arabs. The Arabs after their conquest of Persia, came into contact with an old and refined

civilization. When they were firmly established as a great power, they were not slow to absorb the knowledge of the peoples whom they conquered. They learned arithmetic, algebra, trigonometry, and chemistry from the Hindus; logic, geometry, astronomy and medicine from the Greeks. They realized the treasure house of Greek culture and almost all the available Greek writings were translated into Arabic. They developed chemistry, astronomy, and medicine, and western Europe in the 15th century carried on what the Arabs had preserved. They founded a great University at Cordova in Spain which attracted scholars from England France and Germany who, on their return to their respective countries, took with them the knowledge they had acquired.

As I stated above, it is convenient, but nevertheless a mistake, to regard the advancement of science as a series of "jumps" associated with the names of individuals. Though one is almost forced to adopt this method in any account, there should always be the mental reservation that the method is artificial. What really happens almost invariably, is, that any particular aspect is slowly developed by a number of workers, each of whom profits from the experience of his predecessor and carries the subject a step forward. There arises every now and then a man, who is able to seize on isolated facts and to weave them into a pattern which becomes a theory supported by the facts as then known. When new facts are made available, the particular pattern may change.

It has been no easy task from the mass of material available, to restrict choice to a suitable example to illustrate the gradual development of science. I have chosen an example from the realms of botany which illustrates, not only the idea of development but also the dependence of one science upon another. Our present knowledge of plants as living organisms, i.e. how they live, function, and reproduce themselves and also our views of the oneness of the vegetable kingdom, are of comparatively recent date.

It may be taken for granted that man very early in his history, gained some empirical knowledge of plants. When agriculture became established it must have been known that plants reproduce themselves from seed; that for the development of the seed water was necessary, and that certain seeds had to be sown at certain seasons. The innate curiosity of the human being—a trait we may accept without question—must have led some of the more curious to examine germinating seeds, the development of the seedling to the adult plant and the production of flowers resulting in a further crop of

seed. It is extremely doubtful whether early man's knowledge about plants extended much beyond that stage. The sexual reproduction of plants was of course a closed book though, later, the artificial pollination of the date palm may have aroused the first vague suspicions on the subject. When we come to the historical period we find that Theophrastus, who lived in the 4th century B.C., knew that the roots of plants, acted as more than an anchor for the plant and that through them water is taken up from the soil. This was about the state of knowledge concerning plants up to approximately the middle of the sixteenth century. There was then an intellectual awakening and a few bold spirits realised that nature could not be understood by the study of ancient writings, but that to understand natural problems man must go to nature herself for the answers. One of the first botanists to observe this rule was Corus who helped to make botany a living subject. He incidentally made a guess that ferns reproduce themselves from the "dust" developed on the back of their leaves—a guess which many years later proved to be correct. The real knowledge of the physiology of plants commenced about the year 1621 when van Helmont performed his classical experiment. He showed that a tree grown in a tub over a number of years gained 164 lb. in weight, while the soil only lost a few ounces in weight. Though his deductions from this experiment were wrong, it was only because the necessary chemical knowledge was not yet available, and more than a century had to elapse before the explanation of his observations could be given. He, however, laid down the principle of experimental physiology.

What we know to-day as deficiency diseases—the lack of vitamins in the diet—the cause of which was only discovered at the beginning of this century, have a long and interesting evolutionary history. Beri-beri, for example, was known in China as early as the year 2,600 B.C. The first recorded full description of one such disease, viz. rickets, was given by Francis Glisson in 1650, but a period of nearly three hundred years, during which chemistry and physiology developed, was required for a solution.

The method of development of the embryo both in plants and animals became a matter of investigation and much speculation. Two schools arose, one of which supported the preformation theory, the other the epigenesis theory, though Harvey, as early as the year 1651 from his observations on the mammalian egg, stated that the egg does not contain a

miniature embryo. The controversy continued until well into the nineteenth century before it was finally settled. The microscope now came into prominence in the botanical field. In the hands of Robert Hooke it laid the foundation of all future work on plant anatomy. Hooke, by his observations, may even be said to have launched a new branch of science, viz. cytology. The term "cell" was coined by him in 1665, but the importance of the cell was not fully realised until some two hundred years later. The study of the anatomy of plants was laid down by Grew in England in 1670 and by Malpighi in Italy in 1675. Malpighi observed the absorption of large amounts of water by the roots and its passage through the wood to the leaves and the loss of water from the leaves. He opened a subject of enquiry, viz. the translocation of plant nutriments and the ascent of sap which, even to-day, has not been satisfactorily settled. In his anatomical studies Malpighi, in some of his remarks, foreshadowed the cell-theory formulated almost one hundred and seventy-five years later. Studies in zoology stimulated the examination of plants. At first there were serious attempts to draw analogies between the functions of animals and plants which delayed to some extent the truth concerning the physiology of plants. It was van Leeuwenhoek who gave the great stimulus to the use of the microscope which has since revealed to us wonders of which he could not even have dreamed. In his communication to the Royal Society of London towards the close of the seventeenth century, he described the spermatozoa and asserted that they must penetrate the egg. This is mentioned as it has a bearing on later investigations into reproduction in plants.

The value of experimentation was being more and more realised. Up to the close of the seventeenth century a controversy had arisen as to whether plants were reproduced sexually or not, and Camerarius in the year 1691 by a series of convincing experiments proved that they were, though the real significance of his results had still to wait many years for a true explanation, as the facts of fertilization had yet to be discovered. Another step forward in the ultimate discovery of vitamins was made in the year 1720 when Kramer found that 3 or 4 ounces of lime juice would cure scurvy. An outstanding work on plant physiology was Stephen Hales' "Vegetable Staticks" published in 1727. In this publication Hales describes his experiments on the transpiration of plants and at the same time makes a shrewd guess that plants very probably obtain part of their food from the air. This

had however to remain a guess for another sixty years. The chemist was meanwhile advancing the knowledge of the composition of the atmosphere. Black in 1754 established the existence of carbonic acid both in the free state and in combustion; Scheele in 1775 first isolated nitrogen and, in the following year, Priestly re-discovered oxygen. These were not only important chemical discoveries but they also provided the key that eventually unlocked the door which led to an understanding of both animal and plant physiology.

In 1780, Ingenhousz showed that air rendered foul by the respiration of animals could be purified by plants, but only in the light. A few years later, Senebier established the fact that organic substances are produced by the plant from carbon dioxide and water and that in the process oxygen is given off. An important and fundamental discovery was made by Cavendish in 1784 when he showed that water was a compound of oxygen and hydrogen. Lavoisier about the same time recognised the important fact that respiration was akin to combustion. A further milestone in plant physiology was reached in the year 1804, when de Saussure proved that carbon dioxide provides the green plant with food and that respiration, which all living plants exhibit, is a totally different phenomenon.

The true nature of reproduction in plants was not yet fully understood though, in 1823, Amici observed the extension of the pollen-tube from the pollen-grain on the stigma and followed its growth to the ovule. A discovery of outstanding importance was made by Robert Brown about the same time, when he observed the nucleus of the cell. While the nucleus had previously been seen, it was Brown who insisted on its importance and who stated it to be a normal constituent of all cells. These contributions of Brown's mark a further milestone in cytology. With the improvement of the microscope, research on the cellular structure of animals and plants was stimulated. In the complicated process of cell division, Corus in the year 1824, is said to have been the first to describe the polar bodies which are formed at the time the egg matures.

The organic chemists at the beginning of the nineteenth century made valuable discoveries which have penetrated into all branches of modern physiology and bio-chemistry. In the year 1826, Heurnel prepared synthetic alcohol; two years later Wöhler succeeded in the synthetic preparation of urea, and in 1833, Payen and Persoz isolated the enzyme diastase from germinating barley.

The centre of interest now shifted to the cell and cellular structure and the outcome of these investigations has revolutionized modern biology and medicine. In 1835, Hugo von Mohl recognised that all cells arise from the division of pre-existing cells, though the full significance of this epoch-making discovery was not fully appreciated until many years afterwards. The phenomenon of osmosis, which plays such an important role in plant physiology was discovered by Dutrochet in the year 1837. Living protoplasm—the physical basis of life—which had been seen by Corti in 1772, was described by von Mohl in the year 1838. In the same year Schleiden proved that the nucleated cell is the beginning of the plant embryo and, a year later, Schwann recognised that the egg is a cell. The all-important fact that fertilization of the egg is accompanied by its union with one spermatozoon and one only was demonstrated by Oscar Hertwig. Perhaps the outstanding work of the period on the nucleus, cell-formation, and growth, was carried out by Nageli. In 1844 he established that practically all cell-formation is by cell-division. This work was followed up by Kollicker who stated that the division of the cell is always preceded by the division of the nucleus. The importance of the protoplasm as the vital constituent of the cell was recognised by Nageli and Payen in 1846, while Payen concluded that the contents of the animal and plant cells were composed of essentially the same substance. In the year 1847, Schwann and Schleiden formulated the cell-theory which marks the point at which further progress in botany, zoology and medicine became possible. Hofmeister, between the years 1847-1851, published his epoch-making work in which he demonstrated the alternation of sexual and asexual generations in the cryptogams and so brought order into the proper understanding of the vegetable Kingdom. He also demonstrated that in the division of the mother cells, the nucleus divides into two and that one half of the contents collects round each daughter nucleus. Hofmeister also showed that fertilization in plants was the union of a male and female cell and truly analogous to what takes place in animals. Chromosomes were first described by him in 1848, though their function was still inadequately understood. The first recorded observation of the union of a male and a female cell appears to be that of Thuret who, in 1853, saw the spermatozoids in *Fucus* attach themselves to the egg. In 1855, Virchow maintained the universality of cell-division and contended that every cell is the offspring of a pre-existing cell.

Schultze in 1861, maintained that protoplasm, in general, is similar in all living organisms. The value of these two doctrines, both theoretical and practical, cannot be overestimated. In 1862 an important discovery was made by Sachs who proved that starch was the first visible product of photo-synthesis in plants.

Two completely new avenues in the further study of plants were opened by Mendel and de Bary. In 1865, Mendel by his experiments on garden peas, founded all future work on heredity which, in the hands of men like Hugo de Vries, Bateson, Biffen, and Saunders, has proved of inestimable benefit to mankind. De Bary in the year 1866, published his classic work on the fungi, which marks the beginning of modern mycology. Some years later (1878), Burril, in America, discovered the causal relation of bacteria in plant diseases and opened out a vista which has led to the establishment of a new line of research—plant pathology.

The similarity of the phenomenon of fertilisation in plants and animals, i.e. the fusion of a male and female nucleus, was confirmed in the same year (1879) by Schmitz in the case of animals and by Fol in the case of plants. The mystery which lay hidden for thousands of years, remained a mystery no longer. Over a period of more than two hundred years, from the time Hooke first saw a plant cell in 1665, the contributions of numerous workers elucidated a fundamental phenomenon of all living organisms. In the year 1879 also, commenced a new era in cytology and genetics when Flemming observed the splitting of the chromosomes and, in the same year, Strasburger announced definitely that all nuclei arose from pre-existing nuclei. Four years later van Beneden showed that in the nucleus of the germ cells, the number of chromosomes was half the number found in the somatic cells. During the year 1888-1894, Strasburger, Oventon and Farmer proved the reduction in the number of chromosomes in the gametes of plants, and Strasburger suggested that this reduction occurred in all organisms that reproduce sexually. The first discovery of an ultra virus in plants was made in 1889 by Beijerinck and this opened a fresh line of research on plant diseases. Between the years 1895-1897, one of the last links in the chain of evidence pointing to the relationship of the ferns and *Cycadaceae* was forged, when Hirase (1895) discovered motile sperms in *Ginkgo*, Ikeno (1896) proved their presence in *Cycas* and when Webber (1897) also found them in *Cycas*. The story of fertilization in plants was completed by Nawaschin (1898)

and by Guignard (1899) when they showed that one male nucleus unites with that of the egg, while a second male nucleus unites with the two polar nuclei to form the primary nucleus of the endosperm.

The investigations into the deficiency diseases mentioned previously, were stimulated by Lijkman in the Dutch East Indies. In a series of experiments between the years 1890-1897 he produced beri-beri in hens but showed that if the animals were given unmilled rice or rice with bran added, they recovered. It was not until the year 1912 however, that Hopkins and Funk discovered vitamins, those mysterious substances without which animals cannot live. The work of Hopkins and Funk was the culmination of work by many investigators before their time and has been the starting point for research along similar lines since.

The whole secret of the physiology of plants has not yet been revealed. Within the last year it was shown, that by placing plants in an atmosphere in which the carbon of the carbon-dioxide was made radio-active, a substance, not yet identified chemically, was first formed in the process of photosynthesis and not formaldehyde as was previously accepted. The last few decades have seen so many amazing scientific developments that even an expert can only keep track with a few of them.

The temptation to make the account I have first given more detailed was great but had to be resisted. I hope however that I have been able to show that our present day knowledge is not a thing of yesterday but has gradually been built up by the laborious work of many men in different spheres of science. Every now and then a discovery is made which provides the key to some former discovery and so step by step science advances. It is a slow process of evolution in which the form and shape of science regarded as an organism are influenced at different periods by the acquisition of fresh knowledge. The fundamental structure remains the same but it acquires new parts and possesses new functions.

Where has all this work led us to? It has led us to the grand, fundamental, but simple, truth, which is so little appreciated, that all animal life on the earth is only made possible by green plants utilizing the energy of the sun's light to build up carbon compounds from the carbon dioxide of the air and the water and mineral salts from the soil. It has led us to a true understanding of reproduction in plants, viz. that fertilization is the union of a male and female nucleus. This in turn has enabled the plant geneticist, with

the additional knowledge of the behaviour of chromosomes, to carry out plant breeding on scientific lines. It has led to the greater appreciation of plants as a source of many of the vitamins so essential in the animal diet. It has also led us to the realization that the cell is the unit of life and by its various modifications and functions builds up the living organism. It has led us to the conception that life, as we know it, is only possible because of the exceptional chemical properties of carbon, hydrogen and oxygen, and the physical properties of water. All these facts are probably known, or should be known, to any first year university student in botany, but the sum total has taken the botanist, the zoologist, the chemist, and the physicist, by observation, but chiefly by experiment, over three centuries to prepare—it has been a process of slow but sure advancement.

Besides the above it has taught us to discard theories when unsupported by new facts and to appreciate one of the greatest achievements of science with its emphasis on free enquiry and with the mind itself in command, driven by curiosity and the sense of intellectual adventure (I. Bowman).

One is tempted to expand on the material benefits to man that have flowed from all the academic work I have detailed and to outline its social significance, but this is not the purpose of my address. With the experience we have to-day there is no man living who can afford to be so foolish as to disregard the work of the scientist and to say that it is useless and unpractical.

At the time Robert Boyle and other workers were investigating the properties of gases, Samuel Pepys records the following in his Diary (1.2.1664): "The King came and stayed an hour or two laughing at Sir W. Petty . . . Gresham College (i.e. the Royal Society) he mightily laughed at for spending time only in weighing ayre, and doing nothing else since they sat." The result of Boyle's "weighing ayre" led, however, to the scientific study of gases which has made the steam engine, with all that it implies for man, possible. Mendel, amusing himself in his back garden crossing peas, made possible the breeding of the Marquis Wheat by Saunders—one of the most important food crops of the world. Faraday little thought, while carrying out his "unpractical" experiments on electricity and magnetism, that he was fashioning a tool for the use of man that has almost revolutionized the world. Most of the amenities of modern civilization that we enjoy have flowed direct from the work of those "curious-minded" men who spent their

time "weighing ayre." Those in authority might take the lesson to heart when financial assistance is required for so-called "pure research."

Instead of the example I have chosen, the same theme of gradual development could have been illustrated by examples from other branches of science had the time allowed. For example, the theory of the atom had its germ in Greek philosophy but remained a philosophic conception until the time of Dalton at the beginning of the nineteenth century and developed into the electron theory in the year 1909. Astronomy has advanced along a glorious path since Copernicus published "The Revolutions of the Celestial Orbita" in 1542, and palaeontology since the publication in 1565, of Gesner's illustrated work on fossils. The science of chemistry as a whole, has travelled a long journey since Boyle's publication in 1627 of "The Skeptical Chymist" and a still longer journey if we include the period of the alchemists of the ancient civilizations. The discovery of the hormones by Bayliss and Starling in 1902 and the isolation of insulin by Banting and Best in 1922, goes back to the discovery of Bernard in 1849, that the liver prepares sugar at the expense of the blood passing through it. The discoveries of Crookes and subsequent workers on the cathode rays, had their beginnings in the experiments of Plücher in 1859, and with the later discovery by Röntgen in 1895 of X-rays and of the radiation from uranium by Becquerel in 1896, they opened up a new era in physics. The work of Maxwell and Hertz based on the earlier discoveries of Oersted (1819) and Faraday (1831) has led to the development of modern physics. Modern work on the chromosomes, as for example that of Morgan and his associates on *Drosophila*, has developed by slow stages over a period of almost three centuries since the time of Hooke.

All that I have said was aptly summed up by Dr. A. J. Carlson in an address "Science versus Life" delivered last year. He states: "But as I read the human record in mud, and rocks, and ancient ruins, on tablets of clay, in scratches on stones, papyrus and paper, I think I discern evidence of the ascent of man, through asking all kinds of questions at all times, and seeking the answers by the best methods of the age."

In the evolution of science there have been changing environments which have profoundly influenced the progress of science. The general cultural background of a period, the printing press, the founding of the famous scientific

academies in the latter part of the 17th century and early in the 18th century, politics, philosophical doctrines, geographical exploration, religion, superstition, etc., have throughout the period of which we have any knowledge, hastened or hindered the advancement of science. The Church has played its part in creating an environment in which science struggled for freedom, though it was not antagonistic to science which conformed to its teachings. The Mosaic account of Creation and of the Flood, the belief in a geocentric universe with a heaven and a hell close at hand, for example, delayed the progress of geology and astronomy. Science has gradually but relentlessly broken down some of these barriers. Copernicus exploded the belief in a geocentric universe; geologists brought evidence to bear on the age of the earth; Darwin taught us to think in terms of evolution; Pasteur dispelled the darkness and ignorance concerning disease, and Frazer suggested that we should reconsider our ideas about many of our beliefs and look for their origin in the beliefs held by primitive peoples.

Not only have philosophic and scientific thought at various times created an environment which influenced the advancement of science, but mechanical aids to science have also profoundly influenced the environment in which scientific advance became possible. The microscope, from the simple beginnings of Robert Hooke and van Leeuwenhoek in the 17th century, has played an important role, not only in biology, but also in geology and in metallurgical research. Astronomy could not have advanced without the aid of the telescope, the spectroscope, and the pendulum clock. The photographic plate has been an invaluable aid to science, especially to astronomy, and recently the film has come to the aid of science in the study of the structure and behaviour of micro-organisms. It should not be forgotten that underlying all the numerous mechanical aids to science, are scientific principles discovered by men of science which have been applied and developed over a long period.

When we regard science as an indivisible whole and trace its development, we become more impressed than ever with the influence of changing environments at different periods on the advancement of science. When we look back on the gradual advancement of science from its early beginnings to our times, we must admit that a spirit has been created that should act as a beacon to a better world if men would be guided by the teachings of science. As in organic evolution, mutations may suddenly arise in science

and may persist or die in a longer or shorter period depending on a favourable or unfavourable environment resulting from fresh knowledge. When Newton and Leibnitz about the same time, and probably independently, discovered the fundamental principles of the Calculus it can be regarded as a mutation—something that suddenly appeared and incidentally persisted as one of the most powerful tools ever given to mathematicians. The spanning of the gap between organic and inorganic chemistry was completed in the year 1828 when Wöhler prepared urea from ammonium cyanate,—another example of mutation. Avogadro's hypothesis that equal volumes of gases at the same temperature and pressure, contain the same number of molecules is another example of a mutation that was able to persist in the environment of the Laws of Constant Proportions, Multiple Proportions, and Reciprocal Proportions. The demonstration by Galileo that the acceleration of falling bodies is the same, irrespective of their mass, was a new mutation that appeared in the evolution of science and which has persisted. Ptolemy's views about a fixed earth round which the sun and stars revolved could perhaps be cited as a mutation that persisted until it died in the new knowledge acquired in the sixteenth century.

Another example might be Stahl's phlogiston theory of combustion which could not survive in the environment created by Priestly and Lavoisier. But science does not generally evolve in this manner, but from small continuous variations that may or may not persist. A study of the development of ideas concerning the cell and organic evolution and the conception of the atom for example, will provide numerous illustrations of small or larger variations that have persisted or died in the environment in which they appeared. The evolution of science also provides many examples of a struggle for existence in adverse environments. The veneration of the views and opinions of the Greeks, e.g. Aristotle and Galen; the spirit of superstition that existed for centuries; the attitude of the Church; all provided an unfavourable environment in which science struggled for existence. The fundamental truths of science, while their rapid development was retarded, persisted even under such adverse conditions and flourished and spread.

If you accept my thesis that the origin of science lies in the pre-history period of man and that its advancement is a product of the human intellect, you must also concede that the stage modern science has reached is the greatest

triumph of the human mind. I have often asked myself the question whether the development of science has anything to teach us. I personally think it has. I can never believe that man, notwithstanding the terrible mess he has made of his social and economic problems, has not the brain capacity eventually to solve them. Science has taught us that, when dealing with scientific problems, the subject must be approached with an unbiassed mind willing to be led wherever truth leads and not to be influenced by preconceived ideas or prejudices. The history of science provides us with many examples of theories and beliefs being discarded when fresh facts were brought to light. The world of science is quite unperturbed at such occurrences and accepts them as the price to be paid for a more complete understanding of nature, rejoicing that a step nearer the truth has been attained. Science as such will not solve all our present-day social and economic problems, but I am certain they can be solved if minds trained in scientific methods are brought to bear upon them. When men are prepared to expend the same energy in applying scientific knowledge to large human problems, as they expend on physical inventions, on industry and on commerce, many such problems will be within sight of solution. The intellectual world must have been shocked when Copernicus, on observed facts, stated that the earth moves round the sun and not the sun round the earth; the world was shocked when Darwin stated that the facts of nature did not support the belief in a special creation. Is there any reason why the world of vested interests, the world of greed, the world of selfishness, should not be shocked out of its complacency by the search-light of scientific methods of enquiry. We *know* that the social and economic conditions under which the majority of men live could materially be improved—no proof is needed—they are plain for every thinking man to observe; yet a state of affairs is allowed to continue in our social and economic systems that would not be tolerated for a moment, had they been problems in a matter of pure science. Science can assist to alleviate, and science has assisted in alleviating, the conditions under which human beings live. It remains for the statesman, the administrator, the politician to bring to bear the scientific outlook on the problems we are still faced with. We see in the history of science, how opposition to new thought has again and again been overcome. History also provides us with examples such as the opposition to general education,

the opposition of vested interests to the abolition of slavery, but both were eventually broken.

The whole organic world, the universe, our thought, beliefs, customs, etc., have all undergone a process of slow evolution. In many ways man has consciously assisted evolution in desirable directions in the social and economic spheres. The process has been slow but with the will and the right spirit it can be still further speeded up. There are dangers to be faced, as for example a government forcing a system on the people that may destroy some of their inherent rights as individuals. The average man has not lost imagination nor is he usually a person without a sense of good-will towards his fellows; by mutual trust and co-operation many reforms could spring from below upwards and not be forced from above on the people.

An American sociologist wrote that one of the most terrible examples of un-scientific mindedness is an eminent physical or biological scientist speaking on social matters. As I only lay claim to having some little knowledge of biology, I shall *not* fall into the error of making dogmatic statements, though I consider the awakening interest of scientific workers in social problems which science has created, is a healthy sign of our age. I do, however, make a plea that some of our urgent social problems such as adequate food and housing, the opportunities for the enjoyment of physical fitness and health, be investigated by minds trained in the methods of scientific approach—a method that has solved many problems in the sphere of natural phenomena. One of the methods by which this may be attained, is by some modification to our educational system, whereby young people may be trained, as part of their general education, in the appreciation of science and the scientific method by teachers fully competent to undertake such training. Unfortunately science is not always presented as something living but, as a well-known novelist put it, is presented “as a corpse which bit by bit we painfully dissect.” Intellectual docility is often evidenced in our educational system. More importance is attached to the acquisition of correct beliefs than to the methods by which such beliefs are formed—authority instead of doubt is stressed. A knowledge of the history of science and of thought generally, would stress that the doubting spirit of man has been the chief spur to the advancement of science and to human progress.

In another organisation with which I have had the honour of being associated for many years, I have consistently

advocated the policy of attracting young men of ability to its Councils. The young man with intelligence, approaches many problems unhindered by tradition or conservatism, while the older men of experience, if their minds have not atrophied so that they are unreceptive to new ideas, may act as a steady influence. I consider that in all spheres of consultation on scientific matters the younger men of promise, should be represented on the consultative bodies and their opinions given careful consideration.

It may savour of over-optimism for a generation that has lived through two terrible wars, still to believe that the world can be spared such tragedies and that human beings may live full and useful lives untroubled by the spectre of want in a world of plenty. But I am an optimist. I cannot regard the triumphs of the human mind, as evidenced in one sphere, viz. the advancement of science, as being without some significance and hope. This is more especially the case when we know that civilization has existed for only an infinitesimal fraction of the period since man first appeared upon the earth. Some twentieth century philosophers, as illustrated by Bertrand Russell, are not so optimistic. He writes "the whole temple of man's achievements must inevitably be buried beneath the debris of a universe in ruins—all those things, if not quite beyond dispute, are yet nearly certain that no philosophy which rejects them can hope to stand."

Even if we accept this doctrine, I think there is still ample time for man to re-adjust his affairs, so that like the repentant sinner he may meet his ultimate fate without fear.

In conclusion, I end up on a note typifying the outlook and spirit of science—a verse dedicated to Leonhard Stejneger, the American biologist on the occasion of his ninetieth birthday.

The sons of science walk in endless line
Bearing the torch; a few falter and drop,
But the rest close in: they who have a sign
Far on ahead that reads " You must not stop!"
Their quests are strange and wonderful—to bring
The stars to earth, to take the earth to sky;
To know the *what* of every living thing
Of all times past, and then the *how* and *why*.

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INTERNAL COMBUSTION POWER

BY

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Presidential Address to Section A. read 30th June, 1942.

1. INTRODUCTION.

In modern war the ratio of the mechanical power developed by the application of the internal combustion principle to that developed by other methods must increase several-fold as compared with the peace-time ratio. The main factor contributing to the emergence of this well known war phenomenon is, of course, the urgent necessity for ensuring rapid movement of military personnel and materials. In achieving that object the internal combustion unit has no serious rival, and, as far as all indications point, will retain that supremacy until the advent of the age of "atomic energies," if that age ever comes. The reason is not far to seek. The adoption of some particular prime mover as more suitable than another, for a given purpose, depends broadly on

- (a) The mechanical simplicity and lightness of the unit.
- (b) Its overall thermal efficiency.

Referring to (a) there can be no question but that the turbine form of prime mover is the ideal. Unfortunately, this prime mover cannot be made to meet reasonable demands of efficiency and moderate revolution speed, when required in relatively small units. The turbine form of unit being therefore ruled out as impracticable for most traction purposes, the internal combustion prime mover of the reciprocating type remains without a competitor on either counts (a) or (b). As a reciprocating unit it possesses, for manoeuvring and general operation, a flexibility and low weight which cannot be attained by its rival, the reciprocating steam engine, with its associated auxiliaries. In addition, its higher thermal efficiency, due naturally to the higher temperature limits involved, cannot be denied. It is not (b) however which mainly renders the internal combustion unit attractive in a war-time economy, but (a), since this,

together with the concomitant virtues of rapid and easy adaptation to variations in power demand, meets the exigencies of war transport in a manner which allows of no known substitute. To consider and spend time in developing other forms of prime mover in the hope of forestalling the enemy would be to court certain disaster.

2. THE FOUR STROKE AND THE TWO STROKE METHODS.

These may be termed the "survivals" amongst a host of many other methods proposed for adaptation to reciprocating mechanisms. The patent records of all countries abound in examples of "freak" systems, including "three" and "six stroke" methods, and while their study is interesting and on occasion may even be profitable, the fact remains that they have not succeeded in finding extended practical application.

The definition of a two stroke engine as "a four stroke engine in a hurry" perhaps summarises most concisely the relative characteristics and qualities of these two main types. The best method of comparison is probably made by reference to the two formulae for the mean effective pressure of say. a petrol engine of each type. The expression for the four stroke engine is as follows:—

$$P_m = \frac{\eta_t H P_c}{(1+y) R} \left(\frac{1}{T_a} \right) \text{ lbs. per square inch.} \quad \dots \quad (1)$$

where η_t is the thermal efficiency of the constant volume cycle.

H is the calorific value in ft. lbs. per lb. of fuel supplied.

P_c is the initial compression pressure in lbs. per square inch absolute.

y is the gravimetric ratio of air to fuel.

$R=96$ and T_a is atmospheric air temperature in Deg. Centigrade absolute.

For the two stroke cycle, the mean effective pressure is given by:—

$$P_m = \frac{\eta_t H P_c V_r r}{(1+y) R (m r - 1) T_p} \dots \dots \dots \dots \quad (2)$$

where V_r is the volume of fresh gases retained, in engine cylinder volumes

V_p is scavenging and charging pump volume in engine cylinder volumes

r is compression ratio, usually about 6 to 7.

m is extended volume ratio required for scavenging and charging, usually about 1.2.

T_p is temperature of air delivered from the scavenging and charging pump.

The expression (2) is derived from an application of the well-known Hopkinson theorem which postulates instantaneous and perfect mixing of the exhaust and fresh gases. The whole object of two stroke design is to obviate such mixing and to secure instead, some degree of stratification. A comparison of expressions (1) and (2) however, shows very forcibly the difficulties confronting the two stroke engine designer in his attempts to refute the proverb "the more haste, the less speed"! Each of the expressions (1) and (2), has intentionally been divided into two parts, the first part being common to both. Comparing the two expressions, it is first noted that $|$ is always less than $|$. Hence only the

$$\bar{T}_p \quad \bar{T}_a$$

value of $\frac{V_r r}{mr-1}$ need be examined.

Considering first the ratio V_r ,

it is known that, for instantaneous and perfect mixing $V_r = 0.55$ when $V_p = 0.8$.

$$\text{Therefore } V_r = \frac{1}{1.82}$$

The ratio $\frac{r}{mr-1}$ will be greater than unity when r is greater

than $m r - 1$, i.e. when r is less than $\frac{1}{m-1}$

Taking $m=1.2$, this means that $\frac{r}{mr-1}$ is greater than 1 when r is less than 5

$$\text{If } r=6, \frac{r}{mr-1} = 0.968.$$

Taking, therefore, the $\frac{1}{T_p}$ and $\frac{r}{mr-1}$ factors into account

it can be seen that the mean effective pressure of the two stroke engine on this basis will be approximately one-half that of the four stroke engine. Actually, of course, the two stroke engine designer, by several of his modifications, does obtain some stratification but he has to fight hard for it, and the chance of his two stroke engine ever attaining the same

mean effective pressure as the four stroke unit on comparable terms is very remote. Perhaps the clearest summary of the position is best made by referring to the fact that the two stroke engine, on a weight/power ratio basis has not yet approached the values attained by its four stroke rival. Indeed the difficulties of achieving that result are not altogether summarised by a comparison of formulae (1) and (2) only, for it should further be noted that these formulae do not include deductions due to work done by the scavenging and charging pump or to the extra weight involved in providing scavenging pump volume. Only from the point of view of the valve operating or port control mechanism does the two stroke engine score over its four stroke rival, a simplicity however which requires greater care in design both to overcome the difficulties associated with the short time available for the expulsion of the exhaust gases and introduction of the fresh charge, and to meet the higher temperature stresses involved. It is therefore not without reason that Ricardo gave the advice to all engineers in words somewhat as follows: "For a happy life, have nothing to do with two stroke engines"!

3. SUITABLE RECIPROCATING MECHANISMS FOR INTERNAL COMBUSTION POWER DEVELOPMENT.

Leaving the turbine method out of the picture at this stage, it is perhaps worth while glancing at the problem of providing a suitable mechanism for carrying out the thermodynamic cycle of events involved in applying the internal combustion principle. Both the four and the two stroke methods require a reciprocating piston motion and this can be provided by many types of mechanism. Here again, a search through the patent records discloses a multitude of arrangements for which many absurd claims are made. Out of all this and throughout a development of three-quarters of a century, the ordinary straight four link slider-crank chain mechanism has held its own without, at any time, any serious rival. Included amongst the many inventions brought forward there have been variable stroke mechanisms, such as the Atkinson link motion, eccentric sliding vane engines, swash plate and Z-crank engines, all proposed with the object mainly of increasing the efficiency or reducing the weight of the engine, but so far, none has achieved any extended practical or commercial success. It may be that the recently described Nevatt Z-crank engine of the multi-cylinder barrel type (¹), which appears to be the latest

development in this direction, will yet prove a serious and perhaps successful rival of the standard mechanism.

4. EFFICIENCY OF THE INTERNAL COMBUSTION PRINCIPLE.

Apart from the fact that the relatively greater temperature limits involved in internal combustion motor operation render thermal efficiency values greater than can be obtained from any other type of heat prime mover, many attempts have been made to improve the efficiency by departing from the standard thermodynamic cycles originally followed. The limitations of the standard slider crank chain mechanism involve rejection of the working fluid at the same cylinder volume as for the beginning of compression. This naturally entails the rejection of a fair proportion of energy to the exhaust. To overcome this disadvantage, several variable stroke engines and compound expansion engines have been developed, but none, so far, has succeeded in making any headway. The difficulties are mainly due either to the complicated mechanical linkages or epicyclic gears required, or to the excessive heat losses attendant upon transfer of the gases from one cylinder to another. In any case, the increase in thermal efficiency which is theoretically possible by such means, is relatively small. The efficiency which is practically obtainable appears to be in the neighbourhood of 60 to 90 per cent. of that theoretically possible and is, in general, scarcely worth the extra weight and mechanical complications involved.

An interesting application of extended expansion has, however, been successfully made in the case of the Humphrey Internal Combustion Pump. Here, however, no reciprocating mechanism is involved, the place of the piston and its accompanying connecting rod and crank assembly being taken by a freely moving column of water. The efficiency of this unit is relatively high when compared with an engine of similar compression ratio. Since, however, it operates essentially under low compression ratio, its actual efficiency is no greater than, if as high as, that of a modern compression-ignition oil engine.

It is commonly held that high compression is a *sine qua non* of high efficiency in an internal combustion engine. This is not the case. It can be shown that compression ratios greater than from 9 to 10 do not materially augment, if they augment at all, the efficiencies of the several standard operating thermodynamic cycles of the units in common use.

Compression ratios of 15 to 20, frequently adopted in the compression-ignition oil engines used in transport work, are required for easy starting, and, far from conduced to higher efficiencies, are in the author's opinion, justified only by reason of their assistance in overcoming starting difficulties. Claims that these high compression ratios mean higher thermal efficiencies may safely be discounted. Not only can it be shown that high compression ratios do not necessarily mean high efficiencies for the standard cycles, but that, for some other possible cycles, the efficiency is appreciably reduced by too high a compression ratio. The author has shown (²), also, that cycles are possible which are wholly independent of compression ratio, and one of these is now being followed in the rapid developments at present taking place in gas turbine design and operation. This feature of current practice will be referred to again in a later section.

Another factor which affects the efficiency of operation and, incidentally the energy rejected to exhaust, is the degree of re-association of chemical energy which occurs by the time expansion is complete. This factor has not received the experimental attention it deserves. It is undoubtedly a matter of great difficulty, if not impossible, to assess the degree of this re-association by the sampling of gases at different points of the expansion stroke. There are, however, other methods, such as calorimetry of the exhaust gases under different conditions of engine operation which, if more laborious, would nevertheless provide the necessary data. The author, with the help of his students, at one time or another as opportunity offered, has done some work on these lines and has obtained a fair amount of data confirming the importance of this re-association energy. Some of this was, some years ago, written up and offered for publication but was rejected. Since then more work has been done which confirms the earlier conclusions. This work, however, would require the concentrated attention of a group of workers for several years to obtain the results necessary for a thorough analysis of the phenomena involved. To succumb to parody. "There is more energy in an exhaust gas stream than is dreamt of in our philosophy!"

5. POWER DEVELOPMENT PER UNIT WEIGHT.

This factor immediately calls to mind the chief design requirement for aero engines. The internal combustion unit operates alone in this field and all the indications are that

it cannot be supplanted. There are several reasons for this, including mechanical simplicity, efficiency and mean effective pressure values. The principal development, however, which has placed the internal combustion unit beyond competition is the comparative ease with which its mean effective pressure can be increased. Whether by mechanical or exhaust turbine supercharging it is possible to raise the mean effective pressure to a value well beyond the reach of other prime movers.

Referring first to mechanical supercharging, this has well-defined limits of application. It would appear that the upper limit of mean effective pressure possible is in the neighbourhood of 200 to 250 lbs. per square inch at sea level. This is due to the relatively greater demand made on the engine by the supercharger as the supercharger pressures are increased.

In the case of exhaust turbine supercharging there is no limit to mean effective pressure other than that imposed by the capacity of the materials of construction used, to stand up to thermal and mechanical stresses. The history of the development of this method is interesting and worth some brief attention at this point.

As far as can be ascertained the first attempt to utilise the energy of the exhaust was made some thirty odd years ago by the firm of Messrs. Crossley Bros., Manchester. This attempt was based on observations of the pressure fluctuations in exhaust pipe-lines, in which it was noted that these pressures rose above and fell below atmospheric pressure in conformity with the natural periods of gas column vibration in the pipe-lines. They sought to make use of this by arranging for synchronism between valve timing and the natural periods of gas column vibration so that, at the critical time of engine induction, the exhaust pressure in the cylinder would be below atmospheric pressure. In this way exhaust gas dilution of the working mixture is reduced, and so the engine power increased. This application does not appear to have been particularly successful owing principally to variations in gas column vibration period due to variations in gas density and compressibility under different conditions of operation. It did, however, direct attention to what has since proved to be a matter of considerable practical importance.

The next attempt appears to have been made by Buchi (*), whose method, however, as it finally took shape, not only sought to utilise the natural exhaust pressure depression as

above, but also to apply the energy of the exhaust gases to drive a supercharger through the agency of an exhaust gas turbine. Little was heard of this attempt until it was taken up by Messrs. Brown Boveri and Co., Switzerland, in later years. Meanwhile Rateau (⁴), in France, had been developing exhaust turbine supercharging systems, and these appear to have been used, although not very extensively, in the French Air Force machines during 1914-18. Since then, the method has been the subject of close attention and study by all the aeronautical interests in the leading countries. The nett result of this appears to have been that most of the successful developments took place in America prior to the outbreak of war in 1939. The main difficulty is, of course, the metallurgical one of securing an alloy for the exhaust turbine construction, which will be able to withstand the high thermal stresses induced by an extremely hot gas stream. Mainly for this reason, it would appear, the method has not been carried to much practical application in the machines of the Royal Air Force, in which reliance has been placed rather on the mechanical method of supercharging, in spite of its obvious limitations.

About 1923 (⁵) the author drew attention to the possibility of increased power being derived at altitude from the early diversion of the exhaust gas stream to atmosphere when applying the exhaust gas turbine method of supercharging.

This increased power is obtained by reduction of exhaust gas dilution of the working fluid, although not in the same way as in the Crossley method, and varies from 15 to 20 per cent. extra power according to altitude. The author is not aware whether the method has ever been applied.

In the past two or three years much has been written in the technical press on the so-called Kadenacy method of supercharging. The only apparent difference between this method and that of Crossley is that it seeks to secure the effect of the sub-atmospheric exhaust pressure at the first outflow of the exhaust gases from the cylinder. The claim is made, and probably justifiably so, that the depression of exhaust pressure below atmospheric pressure, is greatest during the first impulsive flow outwards.

The foregoing discussion in this section deals only with methods of augmenting power. Reduction in weight on any appreciable scale would now appear to be possible only by alteration in the orthodox mechanical assemblies commonly applied to reciprocating units. Here, the development of the barrel type engine with Z-crank mechanism, already

referred to in Section 3, would appear to offer the greatest potentialities.

6. COMPARISON BETWEEN AND COMBINATION OF THE INTERNAL AND EXTERNAL COMBUSTION PRINCIPLES.

The main difference between the two principles, apart from differences between the operating temperature ranges, is that two working fluids are required in the external combustion method and one in the internal combustion method. In the former, both fluids, i.e. the combustion gases in the boiler and the steam or other fluid from boiler to engine, require much control attendance, whether manual or automatic. Heat transmission arrangements are necessary throughout, with meticulous attention required to minimise all factors tending to loss of heat. The plant is consequently bulky, heavy and complicated, even when recourse is had to abnormally high boiler pressures. The main factor which has enabled steam plant to predominate in the stationary power field is the steam turbine with its relatively small bulk for a given power, so reducing the overall size of the plant to an extent sufficient to gain the advantage over internal combustion plant comprising reciprocating engine units. It is here that the internal combustion principle has been forced to yield ground to its rival, the latter, however, having had to fight hard by recourse to higher and yet higher pressures and superheats, to achieve an efficiency of operation sufficiently great to warrant its survival. From the nature of things the internal combustion principle stands unchallenged and unchallengeable when thermal efficiencies are in question.

This relation between the two principles has led, in the past, to several interesting suggestions and developments involving the construction of prime movers designed to secure the advantages of both principles. Thus, there has been the Still Engine, of which but little has been heard in recent years, a reciprocating unit in which double-acting pistons developed power by the internal combustion of fuel at one end and by the admission of steam at the other. This steam is raised by the circulation of water through the cylinder jackets, thence to the boiler, which is heated by the exhaust gases discharged from the internal combustion ends of the engine cylinders. The combination is complicated, though sound enough in principle, but the resulting increase in efficiency does not appear to have warranted further commercial development.

A much more interesting and successful practical development is that of the Velox Boiler. Strange as it may appear, one might say that the advent of this unit, a steam power unit, has done more than any other practical factor, to ensure the successful development of the gas turbine. Thus, one might prophesy, a steam unit may yet prove to be one of the main factors responsible for steam power plant ultimately losing its predominating position in the stationary power field. More will be said on this point in a later section.

7. FUELS FOR USE IN APPLICATIONS OF THE INTERNAL COMBUSTION PRINCIPLE.

The suitability of a fuel for internal combustion, so far as reciprocating units are concerned, depends mainly on two factors:

- (a) Its capacity to form an easily combustible and homogeneous mixture with air.
- (b) Its tendency to detonation.

All fuels, of course, are associated with a limiting compression ratio, above which they cannot be used, owing to tendency to pre-ignition. Combustible gases are the ideal fuels and one might say that detonation problems in their undesirable aspect are features encountered mainly in carburetted engines or engines using volatile liquid fuels and depending on spark ignition. Curiously enough the tendency to detonate is, within limits, a desirable characteristic for the fuels of compression-ignition oil-injection engines. The reason for this is that in engines employing oil injection, the delay period after injection and prior to mass combustion, is shorter with detonating fuels. Hence such fuels yield greater efficiency of combustion and higher thermal efficiency when used in oil injection engines.

Reciprocating units have been built for the purpose of employing pulverised solid fuel by direct injection. Indeed, Diesel's first attempts to demonstrate the efficiency of his engine appear to have been carried out using powdered coal. One may safely conclude, however, from the experience already gained in the use of heavy oils, that it is unlikely that pulverised solid fuels can be used with success in reciprocating units.

The case is, however, very different, when consideration is given to the fuel problem in its relation to the internal combustion turbine. This type of unit, now well on the way to extensive commercial application, operates on the constant pressure cycle, sometimes with regeneration and sometimes without. The constant pressure combustion vessel required has no moving parts and the combustion process is not an intermittent one taking place within a small confined volume of varying temperature characteristics through time, but is continuous within a mass of gas at well defined and homogeneous flame temperature. The whole process in the case of the Velox Boiler assembly is carried out within a vessel of relatively commodious proportions, designed for the one purpose of supplying gas at a prearranged temperature and pressure to the boiler flue tubes. These gases have an abnormally high velocity through the flue tubes over which water is also being circulated rapidly. The result is an abnormally high rate of heat transmission across the tubes.

In apparatus of this kind the efficient combustion of heavy and viscous oils and even of pulverised solid fuel, is brought well within the range of practical application, much more so than has proved to be the case for the reciprocating internal combustion unit.

8. STATIONARY POWER PLANT.

The foregoing brief discussions of essential factors relating to internal combustion power development have been given largely in order to lead up to what the author considers to be the most likely developments in power practice in the not very distant future. Taking stationary power plant first, there is little doubt but that the internal combustion turbine will play an ever growing part in stationary power requirements. Its practically complete independence of water supply will, in any case, render its adoption imperative wherever water is a scarce commodity for large scale consumption.

As already stated the emergence of the gas turbine as a serious competitor with the steam turbine was brought about, from the practical point of view at least, by the development of the Velox Boiler. From the thermodynamic point of view this device has most unusual features. It may be defined as a unit in which a system comprising a prime mover (i.e. a gas turbine) driving a compressor mounted on the turbine shaft, with no excess energy available from the shaft for

other purposes, imparts the necessary flow conditions to the discharged gases from the turbine to ensure a high rate of heat transmission during expansion of the gases through boiler flue tubes. It is this rapidly transmitted heat which raises the steam to be used for power purposes. The overall efficiency of the system cannot be high, in spite of absurd performance claims which have been made. Its virtue lies entirely in the extremely high rate of heat transmission obtained. The author has analysed the cycle of operations of the Velox Boiler and its auxiliaries and the results obtained indicate that its thermal efficiency must be relatively low.

It would appear that Messrs. Brown Boveri were much impressed by the high rates of heat transmission obtained in the Velox Boiler and, being about the same time engaged in attempts to develop the Holzwarth explosion turbine, these phenomenal rates of heat transmission induced the firm to turn their attention from the Holzwarth unit to the development of the constant pressure gas turbine employing heat regeneration. Whether or not they had come across analysis published by the author in 1927 (²) relating to this system, the fact remains that they have been following since then the lines of attack recommended in that publication. The analysis indicates that high efficiencies can be obtained while employing low compression ratios associated with heat regeneration, and to Messrs. Brown Boveri belongs the credit of having provided practical demonstration of the soundness of that deduction and of carrying the idea to a successful practical conclusion. Their work will undoubtedly ensure that the internal combustion turbine will have a large say in future developments relating to stationary plant installations.

9. POWER FOR TRANSPORT PURPOSES.

Transport work requires of the prime mover a low ratio of weight and bulk to the power developed. Efficiency, of course, is also an essential factor, but if the first is not obtained, the efficiency factor becomes mainly of secondary importance. It is for this reason that the internal combustion turbine, will never, in the author's opinion, prove a serious rival to the reciprocating unit for transport work. Although the high rates of revolution speed of gas turbine units are conducive to lower weights and less bulk, the fact that these units require to be operated at low compression ratio with heat regeneration will more than counterbalance the high revolution speed advantage in this respect. The

high speeds, too, introduce transmission difficulties and disadvantages which are not the accompaniment of reciprocating installations. The ease with which the mean effective pressures of reciprocating units may be raised by the adoption of exhaust turbine supercharging is, to the author's mind, the determining factor which leads to the conclusion that the reciprocating unit will be hard to beat in the transport field.

An interesting point for discussion, relevant to this subject, is the form which internal combustion power plant for transport is likely to take to meet the fuel exigencies of the future. When natural oil supplies dwindle to a critical stage, as they are bound to do at some future date, it appears likely, in the author's opinion, that gas producer installations operated under pressure will play an important part in staving off serious depletion of both coal and oil supplies. The experimental work involved in determining the factors of importance for the design of such installations should offer no difficulties that cannot be overcome. One hears much of the reduction in power due to a change over from petrol to producer gas. By operating the producer under pressure by means of a turbine supercharger assembly, the power developed can be raised to any desired degree, well beyond the present ratings for cars or commercial vehicles. The same applies, of course, to problems of locomotive and ship propulsion.

10. CONCLUSIONS.

The foregoing somewhat sketchy summary of the position relating to power development by applications of the internal combustion principles has been drawn up for the purpose of giving the author's picture of the power situation as it appears likely to develop in the future. Some of the points of view expressed are undoubtedly coloured by impressions produced in the author's mind by a fairly intensive concentration on the thermal and thermodynamic problems involved. The paper does not give any of the analytical evidence on which the bulk of the conclusions rest. Some of this evidence has already been published at various times, and more, it is hoped, may be published at a later date. In conclusion the author once again ventures the opinion, thus supported, that until the much-heralded age of atomic energies arrives, the internal combustion principle will be called upon to play a continually more important role in all the power developments of the future.

REFERENCES.

- (1) COLIN CAMPBELL: The Axial Engine. *The Automobile Engineer.* December, 1941.
- (2) W. J. WALKER: Regeneration and Regenerative Cycles. *Phil. Mag. (London), Vol. IV. Sept.* (1927).
- (3) A. BUCHI: Über Brennkraftmaschinen. *Zeitschr. f.d. gas. Turbinenwesen*, 1909. 313/329/347.
- (4) A. RATHAU: The Use of the Turbo-Compressor for Attaining the Greatest Speeds in Aviation. *I.Mech.E. Proc. (London)*, June, 1922.
- (5) W. J. WALKER: Aero Engine Supercharging. *Engineering 9th February*, 1923.

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THE FERTILITY OF THE AIR

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Presidential Address to Section B, Read June 29, 1942.

The subject of this address was suggested by the recent Liebig Centenary, for Liebig was one of the first to emphasise the importance of the air as the source of the carbon and nitrogen required by plants. While ample tribute on that occasion was paid to Liebig's contributions to other branches of chemical science, it was very generally assumed that his views on atmospheric ammonia as the primary source of plant nitrogen were quite erroneous, and that his theory on that subject was now quite dead and had merely historical interest.

It is one of the objects of this address to show that Liebig's theory is not only not dead, but that there is overwhelming evidence in its favour. It is not my purpose to revive an ancient controversy but rather to show that no reason for controversy on this simple question of fact ever existed at all and certainly none for the bitterness which the original controversy engendered. My other object is to extend Liebig's theory by showing that not only carbon and nitrogen but the mineral matter of plants—the lime, potash, phosphates, etc. are primarily derived from the air.

The importance of the atmosphere as the primary source of all the chemical elements which enter into the composition of plants has been very generally ignored since the dawn of agricultural science 100 years ago down to the present day.

It is true that in the early years of the 19th Century when the new science of chemistry began to be applied to the problems of plant growth, de Saussure showed that carbon, the most important of the elements contained in plants, was derived from the carbonic acid of the air, but for some years his conclusions were not accepted and such great authorities as Davy and Berzelius believed and taught that the soil humus was the source from which plants derived their carbon as well as the other nutrients necessary for growth.

It was not until 1840 that Liebig finally destroyed the humus theory and since that date it has been very generally accepted that the carbon of plants is derived not from the soil but from the air.

Liebig went further than this, however, and asserted that the source of the nitrogen required by plants was the ammonia which is always present in small quantity in the atmosphere and which is brought down by the rain or absorbed directly by the surface soil.

Then began a bitter controversy which lasted 40 years. The world renowned experiment station of Rothamsted was started about this time and the principal object of the earlier experiments carried out there was to test Liebig's hypothesis. These experiments initiated by Lawes and Gilbert showed that additions of Sulphate of Ammonia to the soil gave a crop increase roughly proportional, within certain limits, to the amount of fertiliser added and the conclusion was drawn that all the nitrogen required by the crop was derived from the soil or from the added fertiliser.

It is evident on close examination, however, that the experiments of Lawes and Gilbert proved nothing in regard to the ultimate source of plant nitrogen but merely showed that, whatever its source, it was generally insufficient to give maximum crops unless supplemented by a nitrogenous fertiliser. Moreover if these experiments had been performed at any one of the experiment stations which were subsequently established in South Africa; the observed facts and the conclusions drawn from them would have been exactly opposite to those reached at Rothamsted.

It is small wonder that Liebig refused to accept the conclusions of Lawes and Gilbert and the bitter controversy went on. The most that can be said for the Rothamsted experiments is that they showed that the nitrogen of plants was derived from the nitrogen of pre-existing plants. They afforded no explanation of the fact that losses of nitrogen in the drainage water and by crop removal would be sufficient to exhaust the nitrogen reserves of most soils in something like 20 years, whereas such exhaustion does not occur even in 100 years of continuous cropping without manure.

Nearly a century after Lawes and Gilbert had shown that an increase of 10 bushels of wheat per acre could be obtained by an application of 86 lbs. of Sulphate of Ammonia, the successors of Lawes and Gilbert, in experiments on the same Broadbalk field at Rothamsted, showed that an increase of 20 bushels per acre could be obtained by simply leaving the land in bare, cultivated, fallow without manure and allowing the winds of heaven to play over its surface for a period of one year.

This looks like a striking confirmation of Liebig's theory that the soil derives ammonia from the air, for the Rothamsted report states definitely that the effect of bare fallow was equivalent to an application of nitrogen. But Rothamsted hesitated to draw the obvious conclusion, for by this time it had unfortunately become the fashion to explain every-

thing that happened in the soil, whether chemical or physical, in terms of bacterial activity, and it was vaguely suggested that the above effect of bare fallow might be explained as due to nitrogen fixation by *Azotobacter chroococcum*.

About the year 1886 Hellriegel and Wilfarth had discovered that certain bacteria living in association with leguminous plants could fix atmospheric nitrogen thus making it available for plant growth and about 15 years later, Beijerinck found that another class of free-living micro-organisms existed which under laboratory conditions could fix a small amount of nitrogen if supplied with relatively large amounts of sugar or other carbohydrate. These facts seemed to furnish an explanation of the ultimate source of plant nitrogen and to put the finishing touches to a long drawn-out controversy. Bacterial fixation of nitrogen in the soil and not the absorption of ammonia from the air constituted the primary source of nitrogen to plants.

If this biological explanation is examined, however, it is evident that whether the nitrogen is fixed by legume bacteria or by free-living organisms in the soil it is necessary in the one case to have a pre-existing living plant or in the other case pre-existing plant residues. According to the terminology of the bacteriologists, these nitrogen-fixing organisms are heterotrophic which is a somewhat obscure way of saying that they require organic matter derived from plants before they can fix even a milligram of nitrogen.

Liebig's dictum that plants came first and humus followed after, is as true to-day as it was 100 years ago and as long as that awkward fact remains, it will be difficult for the bacteriologist to explain how after the eruption of Krakatoa in 1883 when all plant and animal life was destroyed and the islands were covered with a layer of hot ashes and pumice to a depth of 30—60 metres, there followed a luxuriant growth of tropical vegetation in a few years' time.

Current theories cannot explain how an igneous rock devoid of nitrogen can give rise to a soil containing nitrogen sufficient for plant growth. Neither can they explain how the humble lichen can live on a bare inhospitable rock and yet contain as much nitrogen as the grass which is rooted in the soil a few feet away.

To all these questions the theory of Liebig gives a complete and satisfactory answer.

It is worth while, therefore, briefly to re-examine this theory and to review the evidence on which it rests.

As regards the absorption of ammonia from the air by the soil, it is well known that soils—particularly the soil colloids—have a high absorptive capacity for ammonia. Can they absorb it from the air? This question was answered some years before Liebig propounded it, by no less an authority than Michael Faraday who showed that clay (which

is a constituent of most soils) could absorb an appreciable amount of ammonia from the air in a week. It may be objected that Faraday knew nothing of nitrogen-fixing bacteria and therefore ascribed to a physical cause what was really due to biological agency. Fortunately, although Faraday lived before the days of bacteriologists, the possibility of nitrogen fixation by bacteria was automatically excluded because in his experiments the clay was ignited at red-heat and therefore was not only sterile but free from organic matter. This experiment alone is enough to establish the validity of Liebig's theory, and if the name of Faraday is not sufficient to carry conviction, it is open to anyone who doubts Faraday's conclusions to perform the experiment for himself.

In the second half of the 19th Century the question of the absorption of ammonia directly from the air by the soil was studied by various authorities, e.g. Way in 1852. Schloesing (1875) and Heinrich (1881), and the figures given for the amount of ammonia absorbed varied from 25 to 50 lbs. per acre, i.e. an amount sufficient to supply ordinary crop requirements.

With the rise of bacteriological science, however, all interest in possible ammonia absorption ceased and it was rather hastily assumed that any increase of nitrogen in the soil was due to the activity of nitrogen fixing organisms.

Other experiments were devised, however, in which possible bacterial activity was eliminated. Shallow dishes of pure distilled water were exposed to the atmosphere for varying periods and the ammonia content determined. The amount of ammonia-nitrogen thus absorbed was found to be the equivalent of 10 to 40 lbs. per acre per annum. It is true that Hall and Miller of Rothamsted carried out similar experiments and found an absorption of less than 1 lb. per acre. Their experiments, however, are open to the objection that the dishes were covered with very fine wire gauze and hence the free play of air over the surface, which is of fundamental importance, was prevented.

There are other ways in which the ammonia of the air is made available to plants. Rain brings down about 5 lbs. per acre per annum though recent analyses in Ceylon give a figure of 13 lbs. of combined nitrogen. While these amounts are insufficient for full crops they represent an important contribution to the total required. Moreover an appreciable amount of ammonia is adsorbed on the surface of the leaves of a growing crop so that the rain which already contains some ammonia is reinforced by that which is washed off the leaves and this will increase the nitrogen content of the rain from 3 to 5 fold.

Although it has been shown that atmospheric ammonia may reach the soil and the roots of the growing crops in

several different ways, it will generally be insufficient for the high-yielding crops of the present day and, therefore, supplements in the form of nitrogenous fertilisers will still be required, but this does not affect the validity of Liebig's theory.

MINERAL MATTER FROM THE AIR.

Although Liebig considered that both carbon and nitrogen were derived from the air, he believed in common with the vast majority of his contemporaries, that the mineral matter of plants—the lime, phosphates, potash, etc.—was derived from the soil. Any suggestion that an appreciable amount of this mineral matter may be supplied by the air would probably meet with cold disbelief or open hostility. This is due to the very general opinion that the air consists of gases only, viz. oxygen, nitrogen, helium, argon, krypton, neon and carbonic acid with variable amounts of water vapour.

These make up the atmosphere and there seems no room for any mineral content. Yet it can easily be shown that the mineral content of the air amounts in the aggregate to millions of tons and is in a form which makes it easily available for the support of plant life. To take one example only; the lime brought down by the rain although only equal to three parts per million will on a rainfall of 30 inches supply an acre with 18 lbs. of lime or more than sufficient for a normal crop of maize.

To regard the air as consisting of gases only would be as erroneous as to consider the ocean as composed of water only and ignoring the dissolved gases and salts which furnish nutriment to the microscopic marine vegetation and to the teeming population of the sea.

There is of course a certain amount of mineral matter in the air in the form of dust, which is visible as motes in the sunbeam, but this is merely suspended matter, and as it settles to the ground in a still atmosphere it cannot be regarded as a permanent constituent. But there are mineral particles smaller than these which are quite invisible in the sunbeam, and as their diameter is less than one hundred thousandth of a centimetre they never settle but are part and parcel of the atmosphere. They may appropriately be called aerosols or colloids whose dispersion medium is air. They are of great importance to agriculture although their existence is very generally ignored. An acre of soil with its 2 million lbs. of solid matter appears to be the obvious source of plant nutrients, but this is largely a delusion. The solid earth consists almost entirely of inert, insoluble matter of no value as a plant nutrient. Plants draw their mineral requirements from the soil water which is a very dilute solution of mineral salts. A similar solution is obtained by

exposing to the air a shallow dish of distilled water for a few weeks. During that time it becomes a nutrient solution and like the soil solution is able to support plant life. All the 15 chemical elements necessary to plants exist in the air in a form easily assimilable by them and in amounts adequate for growth. This adequacy of the air to supply all the nutritive elements required by plants is shown by the fact, well known to botanists, that certain plants live entirely on air, e.g. *Tillandsia nitida* and certain orchids which have no roots and are quite independent of the soil. They are not botanical freaks, capable of thriving without mineral matter, for chemical analysis shows that they are quite normal in this respect, containing mineral ash and such salts as lime, potash, etc. in amounts of the same order as those of plants grown in the soil. A tree known as the Hottentot fig, *Ficus Natalensis*, partakes of the nature of both kinds of plants for it has aerial as well as terrestrial roots and the former contribute in no small degree to the tree's growth. In emphasising the importance of the atmosphere as being able to supply all that a plant needs for growth, it is not intended to ignore the important part which the soil plays in the growth of ordinary crops.

Such crops are rooted in the soil and therefore soil fertility is an important factor. But everything points to the fact that such fertility was derived originally from the air and the function of the soil is to act as a medium for storing up reserves of plant food and especially moisture. Soil fertility is usually confined to a few inches near the surface. It is significant that the subsoil is generally sterile and the highest fertility is found in the top layer which is furthest from the parent rock and nearest to the atmosphere.

In a recent issue of *Nature* is an account of some interesting experiments in which the surface inch of soil was carefully removed and spread on an equal area of another part of the same field with the result that there was an increase of 80% in the cotton crop. The top-dressing of golf greens affords similar evidence of the value of the surface soil.

A School has recently arisen of Russian Scientists who have studied the genesis of soils and have reached the remarkable conclusion that the nature of a soil depends quite as much on the climate as on the geological character of the parent rock. They rightly emphasise the important effect of weathering in changing the character of the original soil almost beyond recognition. By weathering is meant the effect of wind and rain and especially the carbonic acid dissolved in the latter. By these means the parent rock undergoes disintegration and transformation into something quite different in appearance and physical characteristics, and what were merely mineral particles become a soil. But these Russian Scientists did not explain how such a soil

acquired its fertility and became capable of supporting plant life. About 15 chemical elements are necessary to build up the plant's structure and of these comparatively few exist in the rock from which the soil has been derived. Whence came the nitrogen and the other elements which are not found in the parent rock but which exist in the surface soil? They are obviously derived from the air, from the winds which sweep over its surface and they are dissolved and carried down into the soil by every rain that falls. The phenomenon is one of absorption at the surface of the soil and although the concentration of these elements in the atmosphere is extremely small the effect is multiplied a thousand-fold owing to the fact that the air is always in motion with a velocity ranging from 1—50 miles an hour or more.

When the crop is established and in a state of active growth further adsorption of mineral matter from the air takes place at the surface of the leaves and this in turn is washed off into the soil by rain and reaches the plant through its roots.

When once the soil has become a suitable medium for plant growth its fertility increases more rapidly because the plant itself reacts on the soil, and the humus, derived from the decay of crop residues, is of great value in improving the physical condition of the soil and in contributing to the building up of plant food reserves in its surface. It is at this stage that the soil bacteria do their beneficent work. Their function is to destroy rather than to build up and their chief work in the soil is to break down dead vegetable matter, resolving it into simpler compounds and so making it available for other crops. In this way a thrifty Nature is able to use the same atoms over and over again and at the same time to prevent a wasteful accumulation of dead matter.

If it is conceded that the air plays an important part in plant nutrition and in the genesis of a fertile soil it may perhaps be said that this fact has no bearing on practical agriculture. As there are no means of modifying appreciably the composition of the atmosphere, it would seem that there is no scope for the use of fertilisers and no need for the usual operations associated with the cultivation of the soil. This is an erroneous view, however, for fertilisers will still be necessary in many instances and fortunately owing to the fact that most crops are rooted in the soil it is possible to make good any deficiencies by applying fertilisers and manures in close proximity to the feeding roots. Tillage operations and various measures for improving the physical condition of the soil will also be necessary to enable it to make the best use, by absorption or otherwise of the fertilising elements in the air which passes over its surface.

This conception of the surface soil as acquiring fertility from the air serves to emphasise the importance of measures to prevent erosion. It has been estimated that it takes at least 100 years to make one inch of fertile soil. Cropping does not exhaust its fertility, but sheet erosion will in a single season remove that inch of soil bodily, leaving exposed the comparatively sterile soil beneath.

It will not have escaped the notice of my hearers that if plants derive their nourishment from the air and then serve as the food of man, it may be claimed that man too, at one remove, is living on air. It is possible to go further and say that the physical structure of man has been built up, atom by atom, not out of the dust of the earth but from the winds of heaven. The intermediate agent by which this has been accomplished is the living plant.

The germinating seed, moved by the mysterious life impulse within, draws from the surrounding air those invisible elements which are necessary to growth and, more wonderful than the poet's pen

. . . . turns them to shapes

And gives to airy nothing a local habitation and a name.

Out of nothing more substantial than the invisible air and solar radiation, the living plant builds up organic compounds which are marvels of molecular architecture. More powerful than the poet's imagination it bodies forth the forms of things unknown and brings the invisible into the light of day.

The botanist would probably say that the plant exhibits the phenomenon of growth, but the chemist looking beneath the surface and probing into questions of atomic configuration and molecular structure, knows that it is something more than that, and that here the great drama of creation is being unfolded daily before our eyes. Chlorophyll, enzymes, starches, sugars, proteins, cellulose and a hundred other compounds are synthesised from the air with infinite ease and in endless variety.

These are not produced at random by blind chance but in orderly sequence, moving towards a predetermined end, and to one harmonious whole, which is the mature plant. The first of these syntheses is that of chlorophyll, which is an essential preliminary to the utilisation of solar radiation in building up organic compounds from carbonic acid at a later stage of growth. One can hardly help saying that Chlorophyll is synthesised for the express purpose of utilising solar energy. I may perhaps be reproved for introducing teleological conceptions into chemical science, but it is impossible to avoid it when dealing with the living plant, for the moment the mysterious life element came into these systems of atoms, molecules and blind forces, the character

of the world was changed. The very word synthesis implies creative activity under the direction of a controlling mind, and the entity called life takes the aimless atoms and wandering ions of chemical science and gives them direction.

Some of the organic compounds, e.g. sugar, which the plant builds up from carbon, oxygen and hydrogen can be synthesised in the laboratory from the same primary elements. In this case at any rate there is no difficulty in finding purpose and a directing intelligence. Those who are in search of evidences of purpose and design in Nature need go no further than the living plant, whether it is the rose of Sharon or the meanest flower that blows.

I have spoken of the fertility of the air. Is it inexhaustible and will it continue to supply the needs of plants and animals for countless generations? The reply is that if the fertilising elements of the air were not renewed they would be exhausted in a comparatively short time. Thus it has been computed that the carbonic acid in the air is only sufficient to provide for plant growth for 35 years. But it is being constantly renewed partly by the decomposition of organic matter in the soil, partly by the combustion of carbon-containing substances and partly from the sea. The sea, too, is probably the source from which ammonia and the various mineral substances are replenished. It is significant, for instance, that of all the mineral substances absorbed from the air or brought down by the rain there is a preponderance of sodium chloride, while the iodine present in the air also suggests a marine origin.

It appears therefore that the stuff of life circulates, in ceaseless flow, from the sea to the air, from the air to the soil and from the soil to the sea.

REFERENCES.

- INGHAM, G. (1939): Atmospheric Ammonia as the Primary Source of Nitrogen to Plants. *This Journal*, XXXVI, 158-163.
INGHAM, G. (1940): Fallowing in relation to the Nitrogen Supply. *Journal S.A. Chemical Institute*, XXIII, 52-58.

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THE THORNVELD TREE: A NOTE ON PLANT ADAPTATION

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INTRODUCTION.

In recent years a number of presidential addresses to this Section have discussed the opportunities which South Africa presents to the botanist. E. P. Phillips in 1930 showed how botanists of the past by availing themselves of these opportunities have placed South Africa on the botanical map. John Phillips in 1936 drew attention to the major problems which confront South African biologists as a result of agricultural and industrial development, and indicated the kind of knowledge required before these problems can be solved. Last year Dyer reminded us of the opportunities and responsibilities arising from increased contact with and interest in the great continent to our north.

In view of these previous addresses it is not necessary for me to present yet another general review of the opportunities of South African botany, and I propose to discuss these opportunities within the more restricted field of plant adaptation. In doing this I shall refer in particular to some of the work we have been doing in Natal.

General studies of Plant Ecology in South Africa have progressed rapidly in the last twenty years. We have a good idea of our major plant formations, and the details of the plant succession are in the process of being cleared up. The necessity of possessing this information for the proper conservation and utilisation of our natural resources is now generally recognised, and this has stimulated the more detailed studies as far as our pastures and forests are concerned. There remains, however, a tremendous field for detailed ecological studies of all our natural vegetation types. Owing to the great range of climatic and soil conditions, and the relative great age of our land surface, we are in a favourable position to make contributions which will not only be of great value to our own country, but will also be of considerable general importance.

The striking growth forms of many of the plants from the more arid parts of South Africa attracted the attention of our earliest botanists, and they are still objects of considerable general interest. The earlier attempts to explain the adaptations of these forms were based on teleological reasoning. Though we are not yet able to avoid teleology completely, considerable progress has been made in approaching these questions from an experimental point of view. I may refer, for instance, to Henrici's work (Henrici, 1927, 1937, 1940) on the water relations of some of our karroid forms, which has served to clarify our knowledge of the nature of the adaptations of these plants to the fluctuating values of their environmental factors.

THE THORNVELD ENVIRONMENT.

In Natal plants do not have to contend with the extremely arid conditions to which so much of our South African flora is subject. But even under our comparatively favourable conditions there is the necessity for the integration of plant form and function to suit particular habitats. One of these habitats to which we have paid some attention in recent years is that of the Natal Thornveld—or as it has been called (Bayer, 1938), the Deciduous Short Tree Savanna.

The mean annual rainfall of much of our Thornveld is in excess of 30 ins. (75 cms.), the mean annual temperature about 66° F. (19° C.), and the mean relative humidity about 66 per cent. (Union Meteorological Office Reports, 1939, 1942). These figures would indicate conditions relatively favourable for plant life. Actually, however, these mean values do not tell us enough about the thornveld environment. It is important to realise that practically all the rain falls in summer, and that there may be periods of as long as three months during which no fall of rain is experienced; that maximum temperatures may exceed 110° F. (43° C.); minimum temperatures may fall as low as 20° F. (-7° C.); and that atmospheric relative humidity may be less than five per cent. It then becomes clear that the conditions are not as favourable as the mean values would lead us to believe. It is the extreme values which are of the greatest ecological significance. Even though they operate only occasionally, they nevertheless represent limiting factors, and only plants which can withstand these extreme conditions can succeed in the thornveld environment.

Perhaps the most important of these limiting factors are the long winter drought, the high evaporation intensity of the air on days on which the temperature exceeds 100° F. (38° C.) and relative humidity is less than 15 per cent., and the low minimum temperatures recorded on clear winter

nights. To these extreme physical factors we must add that of the veld fire.

Thornveld is a result of the invasion of grassland by trees. The dominant trees are usually fairly widely spaced (20 to 60 or more yards apart) and seldom exceed 12 or 15 feet in height. The chief of these are a number of species of *Acacia*, such as *A. karroo*, *A. arabica*, *A. caffra*, and *A. robusta*, and a few leafless, succulent species of *Euphorbia*, such as *E. ingens*, *E. triangularis*, and *E. tirucalli*. Other common trees include species of *Gymnosporia*, *Cassine*, *Doryalis* and *Zizyphus*.

The *Acacia* species have doubly compound leaves with small, hard pinules; the leaves of the *Euphorbias* are soon discarded and their functions are taken over by the swollen, succulent stems. In the case of the other species the leaves are usually small (less than three inches long), hard and leathery. They are all small, light demanding, profusely branched, spinescent, deciduous or semi-deciduous trees or shrubs, able to stand out above the grasses, fully exposed to the action of all the factors of the environment. It is particularly from the point of view of their capacity to resist the extreme factors of the environment discussed above, that we must consider the adaptations of these plants.

SUCCULENTS.

In considering the adaptations of thornveld trees it is necessary to distinguish between the succulents and non-succulents. The rooting system of succulents is generally shallow, and these plants survive drought by virtue of their capacity to store up and conserve a relatively enormous water supply. We have confirmed the results of other workers (Maximov, Henrici) that both stem and leaf succulents have a low sap osmotic pressure and a very low transpiration rate. The quantity of water stored is apparently far in excess of their actual transpiration requirements, and they are able to maintain a slow, steady transpiration rate for a long time after they are deprived of an external water supply.

The aeration and water conducting systems of succulents are reduced. The reduced aerating system is probably an important factor in decreasing transpiration rate. On the other hand the conducting system may not be as inefficient as is sometimes suggested, as some succulents exhibit a marked increase in water content soon after even light showers of rain (Bews and Vanderplank).

The great bulk of water in these plants must be of some assistance in maintaining a fairly even temperature, and in itself may provide some protection against damage by frost or fire. It has been noted, however, that succulents are often absent from valleys subject to severe cold as a result of cold

air drainage. The water relations of succulents are such that they are able to grow on very shallow soils, or on soils which have a very rapid water drainage. In such situations grass cover is sparse and they are comparatively immune from the effects of veld fires.

NON-SUCCULENTS.

ROOT SYSTEM.

In the case of the non-succulent, usually sclerophyllous, thornveld trees, the picture is quite different. The average height of the aerial system is only ten or twelve feet, but it is combined with an extensive root system. This consists of one or more deeply penetrating roots together with a widely spreading system of surface roots. Roots of *Acacia karroo* are hardly decreased in diameter at a depth of over 20 feet below ground, and I understand that the roots of some *Acacia* species can penetrate to a depth of 70 feet. We have also traced the surface roots to a distance of 60 feet from the base of a tree. It is likely that in most of the non-succulent thornveld trees the underground system is far more extensive than the aerial system. Though under natural conditions our thornveld trees may be comparatively widely spaced, it is possible that there exists between them an appreciable root competition. We have perhaps been inclined to overlook this possibility.

RAMIFICATION.

An interesting character of thornveld trees that has been somewhat neglected is the production of axillary leaf fascicles. This is well shown in a number of species of *Acacia*, *Gymnosporia*, *Cassine*, *Capparis*, *Dichrostachys*, *Doryalis*, etc. These fascicles are dwarfed branches which are able to produce new leaves without the necessity of producing new wood. The advantage of this is apparent when during dry springs or summers we find these plants producing an extensive new assimilating system with a negligible production of non-assimilating tissue.

The characteristic of fascicle production also provides these plants with a means of withstanding the damaging effects of atmospheric desiccation, of frost, or of fire. The death of tender shoots from any of these agencies hardly affects leaf production, since it also stimulated fascicle development from older wood, where the fascicle buds have been protected by the thicker bark. We have noted that after a severe winter frost (9° F. of frost), during which comparatively large branches were killed, leaf fascicle production occurred in the following spring, in the case of *Acacia arabica*, even from the base of stems six inches in

diameter. The thick bark so characteristic of thornveld tree species, together with the attribute of fascicle production, must represent a valuable protective adaptation.

An unusual habit noted in the case of some of our thornveld *Acacia* species is the dying back of saplings to ground level. This occurs for about the first four years of their life, but each year the new shoot attains a greater size. After a height of three or four feet is reached the dying back process ceases and the stem is permanently established. This behaviour may also be regarded as possessing a value in preventing the destruction of the sapling by grass fire, by drought, or by severe frost, until a shoot is developed whose bark is thick enough to provide more adequate protection to the underlying fascicle buds. This habit seems connected with that of fascicle production, since we have noted it for species such as *Acacia karroo*, *A. arabica* and *A. robusta*, all of which produce fascicles, but it does not seem to occur in *Acacia lasiopetala*, in which fascicles are usually absent.

Recent discoveries of the effects of plant growth hormones might permit the suggestion that the extreme ramification of thornveld trees, which apparently reaches its ultimate expression in the production of numerous axillary fascicles, is due to reduced auxin production by apical buds. The fact that young plants of *Acacia karroo*, *A. arabica* and *A. robusta*, exhibit a much slower growth rate than do those of *A. lasiopetala*, adds support to this suggestion. Indeed we might find here the explanation of the general small size of thornveld trees, and of the ageotropic behaviour of their branches, and thus provide a physiological clue to the evolution of the "umbrella" type of tree form. Since the development of most of these characteristics seems more pronounced under drier conditions, it seems possible that decreased auxin production, if it does occur, is a response to increased aridity of the environment.

THORN DEVELOPMENT.

The production of branch or of stipular spines is characteristic of thornveld trees, as the very name Thornveld indicates. Spines of this sort are common in forest climbers, but comparatively rare in forest trees. A few of our forest trees are truly spinescent (*Scolopia spp.*, *Chaetacme aristata*), but in other cases the recorded "spinescence" is due to the production of prickles from the bark (*Fagara spp.*), and is not due to modification of branches or stipules.

There can be no doubt that the production of branch spines is related to aridity, and the fact that young branches are easily killed by desiccation provides a clue to the origin of this type of spine. On the other hand the evolution of stipular spines is not so easily explained. It is notable that

in the case of thornveld trees the stipules are either small, or if large are always spinescent. In some cases indeed, spinescent stipules may attain a length of six or seven inches (15 to 17 cms.). It is worth recording that in the Natal Thornveld species of *Acacia*, the spine bearers also produce leaf fascicles; whereas the prickle bearing species, which include the climbers, produce neither leaf fascicles nor spinescent stipules.

I am not aware of any of our forest trees that produce spinescent stipules, though in some of them (*Cunonia capensis*, *Ficus spp.*) the stipules are fairly large, and may exceed an inch (2.5 cms.) in length. Spinescent stipules apparently also represent a reaction to aridity, and it would seem that the character has been evolved in species with large stipules, or that increased lignification of stipules has allowed them to develop to an abnormally large size. It may be suggested in this connection that aridity has had a double effect. By retarding the activity of apical buds it has permitted the development of enlarged stipules, and at the same time increased their lignification.

WATER RELATIONS.

The advantage of an extensive surface, as well as a deeply penetrating root system, is that the plant can obtain water both from surface soil and from the deeper and more permanent ground water. The deeper source of water is most important under drought conditions when surface moisture becomes unavailable. It is not sufficiently realised that even during drought periods these plants do not necessarily lack a supply of water. By means of their deeper roots they may be in contact with a good supply of water. As far as their water relations are concerned, once they have established contact with the deeper soil water, their problem is not that of obtaining water, but that of transferring the water fast enough to satisfy the high transpiration demand resulting from the dry atmosphere surrounding their leaves.

Measurements of the specific conductivities of the stems of thornveld trees show that they are often higher than is the case with our forest trees. In thornveld species the transverse membranes of the vessel elements are as wide as the vessels themselves, thus the full conducting capacity of the vessels can be effectively utilised. In the case of forest trees species the perforations of the transverse septa do not extend to the full width of the tracheae, and these constrictions must reduce the conducting efficiency of the vessels. It has been shown (Bews and Bayer, 1931) that the actual conduction of the individual vessels is greater for thornveld species than for evergreen forest trees.

In spite of the apparent high conducting efficiency of the wood, under conditions of high evaporating power, the leaves of thornveld trees undoubtedly experience a pronounced water deficit. We have recorded decreases in leaf water content from morning to mid-day of over 10 per cent. When we remember that the leaves of temperate mesophytes are killed by a fall in leaf water content of two per cent. (Knight, 1922), it would appear that the leaves of thornveld trees have much greater powers of withstanding desiccation. In this connection it is noteworthy that the leaves of most thornveld trees never wilt. Perhaps the thick cuticles and the relatively large amount of woody tissue in these leaves serve the significant purpose of preventing wilting or deformation of the leaf even under conditions of great desiccation.

We have determined the amount of water transpired by a small specimen of *Acacia arabica*. This tree was about five feet in height, with a crown diameter of four feet. Its 13,000 leaves gave a fresh weight of almost exactly two kilograms. Assuming that the transpiration rate of this tree was the same as that of a neighbouring specimen of the same species, we calculated that on a hot summer's day (Max. temp. 92.5.F., lowest Relative Humidity 24%), this tree lost very nearly five litres of water from 10 a.m. to 4 p.m. At maximum transpiration the water would need to pass up the stem at a rate of 40 c.c. per sq. cm. cross section of wood per hour. Under a pressure of 30 cms. of mercury the wood of this species can carry 30 c.c. of water per sq. cm. per hour. Since the leaves could undoubtedly exert a higher tension than this, 40 c.c. per hour seems to be well within the conducting capacity of the wood. These calculations suggest that water deficit in the leaves is not due to lack of conducting efficiency of the wood, but is more likely due to slow movement of water through the soil, or to inability of the root hairs to supply water fast enough to the plant.

The osmotic pressure of extracted leaf saps of thornveld trees is high. It varies from about 27 to 40 atmospheres, with a mean value of about 30 atmospheres. The presence of a leaf sap with such a high osmotic value would indicate that the leaves could, under conditions of low water content, exert a high suction pressure. This might be most important in permitting the plants to draw water through their long surface and deeply penetrating roots, or in absorbing water from a fairly dry soil. We might expect, therefore, that the sap in the conducting channels of thornveld trees must be under a fairly high tension.

Attempts to determine these tensions by attaching manometers to stems of thornveld trees have not been very successful. Our highest record is a tension of 61 cms. of

mercury. This would be sufficient to raise a column of water 27 feet (8 m.). Since there is also the resistance of the vessels to be overcome the effective height as far as the plant is concerned would be considerably less than this figure. So we cannot claim to have demonstrated a vessel sap tension sufficient to draw water from any great depth.

Our difficulty with this method of measuring vessel sap tensions is the development of air bubbles at the junction of the manometer and the stem. These occur at tensions as low as 20 cms. of mercury. If a piece of fresh stem is cut and decorticated under water, air can be drawn out of the wood at tensions as low as 12 cms. of mercury. This can hardly represent air which is being drawn out of solution from the vessel sap, and must represent free air in the wood. Since it seems impossible to attach a manometer to a stem so as to avoid connection with air in the wood, we can hardly expect that manometric methods will provide a true value of the actual vessel sap tensions.

The transpiration rate of thornveld trees is also high; far higher per unit fresh weight of leaves than is that of forest trees. Under some conditions the amount transpired is as high as 1.5 times the fresh weight of the leaves. Such high values may occur in any season of the year. As a rule, however, a very high rate of transpiration is not maintained for long, but is soon followed by a fall, during which transpiration may be very low.

On days on which the maximum temperature does not exceed 80° F. (27° C.) and relative humidity does not fall below 40 per cent., the transpiration rate, both in summer and in winter, increases steadily during the forenoon to a maximum towards mid-day. This is followed by a steady fall during the afternoon. Since transpiration rate in winter, when surface soil moisture may be as low as 8 per cent. (dry weight basis), is about as high as that in summer, it would seem that the plants must be making use of the deeper seated soil water.

On hot days, when maximum temperatures exceed 90° F. (32° C.) and relative humidity is less than 30 per cent., transpiration rate increases rapidly to a maximum at 9 or 10 a.m. By this time it may exceed the maximum attained on milder days. This early maximum is followed by a rapid fall, and thereafter transpiration is erratic and fluctuates sharply until 2 or 3 p.m. After 3 p.m. the rate is moderate and falls off steadily towards evening. The fluctuations in transpiration rate follow closely changes in leaf water content, and it would appear that under these conditions transpiration demand is only slightly in excess of water supply. This produces fluctuations in both transpiration and leaf water content throughout the mid-day period.

Under extremely dry conditions, when relative humidity falls below 20 per cent., and temperatures are over 96° F. (36° C.), the early transpiration maximum may be followed by complete cessation of transpiration until the late afternoon. This cessation of transpiration is sometimes accompanied by stomatal closure, but we are not yet able to say whether this occurs in all cases. We have also not yet determined whether stomatal closure is due to leaf water deficit, or to a more direct response on the part of the guard cells to high temperature or low atmospheric humidity.

We can summarise our results by stating that the transpiration rate of thornveld trees is normally high, but the rate is subject to sharp fluctuations, and an erratic transpiration march is a feature of thornveld trees.

CONCLUSION.

The few comparisons we have made indicate, that as compared with forest trees, thornveld trees are physiologically plastic; they possess a much greater latitude of functional response to environmental changes. Physiological plasticity is perhaps to be expected in plants adapted to an environment with a wide range of factor values, but is nevertheless of considerable importance. While it may permit spread over a wide geographical range, it may also retard the production of new species. Functional plasticity is apparently a feature of species which appear early in the plant succession, and it may be on this account that pioneer species, though comparatively few in numbers, have a wide distribution. On the other hand species which appear later in the succession are physiologically more stable, and though greater in numbers, have a more restricted distribution (Bews, 1925).

Another aspect of these investigations which is of particular interest, is that though still in the preliminary stages, they have taken us far enough to show that in studies of this sort little real progress can be made by mere study of the behaviour of the individual organs. It is the integration of the functions of the different organs within the organism as a whole which is all important. Indeed we have to consider more than this, we have to discover the nature of the blending of the functions of the organism with the whole complex of factors which constitute the environment. In this respect the plant physiologist has much to learn from the ecologist. Ecologists have realised the necessity of adopting a holistic viewpoint when considering relationships within the organism-community-environment complex, but this attitude has not yet been generally adopted by plant physiologists. This is indicated by the general failure of our physiology text books to indicate how the various plant

functions, as for instance their water and assimilation economies, are interminably intertwined.

Hitherto, practically all attempts at the classification of plant forms have been based on a consideration of purely morphological characters. The result is that we are presented with a number of categories of plant forms, without any suggestion of the relationship of the various forms to one another. Bews, in the greatest contribution which he made to Botany (Bews, 1925, 1927), has pointed out, however, how by adopting an ecological approach to this subject and considering also the relationship of the forms to their environment, it might be possible to classify plant forms in an evolutionary sequence. He showed that on the eastern side of South Africa we have a whole series of plant forms produced as a reaction to increasing aridity in the environment, and that the whole course of the evolution of these forms, from that of the tropical tree to that of the karroid shrub, is displayed for us on a grand scale. The evidence he presented in favour of the thesis that the tropical tree form is more primitive, and that the forms adapted to more arid conditions are derivative is most impressive, and has not yet received its proper appreciation.

The full expansion of Bews' ideas is not yet possible, owing to the inadequacy of our knowledge of the functional behaviour of the various forms. He has, however, shown us the light, and we must admit that his suggestions have opened up a great opportunity for South African plant physiologists. By more detailed studies of the functional significance of plant adaptations, we can clear the way for an evolutionary classification of plant forms, and this accomplishment still remains one of the great aims of Botany.

Studies such as I have discussed of the relationship of plants to their environment are of more than academic interest. In attempting to understand plant adaptation we also learn a great deal about the environment itself, and sometimes discover the existence of unexpected environmental factors. As an instance, I may quote how our studies on the march of transpiration led us to investigate atmospheric humidity, with the resulting discovery of the occasional intense mid-day drought of the thornveld environment (Bayer and Coutts, 1938). This thorough understanding of the environment and of its effects on plants is fundamental to our endeavours to make proper use of our natural resources. It is lack of just this exact knowledge which has been the cause of the failure of some of our land settlement and irrigation schemes, and of the tragedy of veld and soil deterioration.

In conclusion I wish to explain that the studies of the water relationships of thornveld trees that I have discussed,

have been carried out over a number of years by various botany students at the Natal University College. In most cases these students have still been in the undergraduate stage, but we have found that requiring such students to undertake minor pieces of investigation which involve a good deal of critical discussion and testing of conclusions, provides a valuable introduction to scientific research methods.

I make no apology for discussing a subject which has been tackled in such a piecemeal manner, and which still requires much further investigation. My experience as a matriculation examiner for a number of years, has taught me that the whole subject of plant adaptation is one about which our present generation of botany teachers entertain the most peculiar misconceptions. I feel that those of us who are responsible for the botanical training of the future teachers, can perform a valuable service to our science by clearing up some of these misconceptions, and it is partly to provide a lead in this direction that I have ventured to discuss a subject about which we are still comparatively ignorant.

It is only recently that plant physiologists in South Africa have started to take their laboratories into the field. and judging by a number of papers which have been published recently, it is becoming the fashionable thing to do. This is all to the good. By learning to understand how our plants work under natural conditions, we can make a valuable contribution towards a clearer understanding of the relationship and inter-relationship of organism and environment, and thereby enrich both our country and our science.

SUMMARY.

South Africa is considered a favourable country for studies in plant adaptation. The Thornveld environment is described, and a discussion follows of thornveld plant characters which may possess adaptative value. Physiological investigations of water relations are summarised, and emphasis is placed on economic and theoretical value of studies of plant adaptation.

BIBLIOGRAPHY.

- BAYER, A. W.: *Ann. Natal Museum.* VIII. 3. 371-454 (1938).
- BAYER, A. W. AND COUTTS, J. R. H.: *This Journal.* XXXV. 154-157 (1938).
- BEWS, J. W.: *Plant Forms.* London (1925).
- BEWS, J. W.: *Ecological Evolution of Angiosperms.* London (1927).
- BEWS, J. W. AND BAYER, A. W.: *This Journ.* XXVIII. 173-179 (1931).
- BEWS, J. W. AND VANDERPLANK, J. E.: *Ann. Bot.* XLIV. 699-719 (1930).

- DYER, R. A.: *This Journal*. XXXVIII. 56-68 (1942).
- HENRICI, M.: 11th and 12th Repts. Direct. Vet. End. and Res. (1927).
- HENRICI, M.: 13th and 14th Repts. Direct. Vet. End. and Res. (1928).
- HENRICI, M.: *This Journ.* XXXIV. 61-72 (1937).
- HENRICI, M.: Dept. Agric. and Forestry. Plant Indust. Series. No. 39 (1940).
- KNIGHT, R. C.: *Ann. Bot.* XXXVII, 361 (1922).
- MAXIMOV, N. A.: The Plant in Relation to Water. New York (1930).
- PHILLIPS, E. P.: *This Journal*. XXVII. 39-80 (1930).
- PHILLIPS, JOHN: *This Journal*. XXXIII. 24-45 (1937).
- UNION METEOROLOGICAL OFFICE: Rainfall Normals (1939).
- UNION METEOROLOGICAL OFFICE: Temperature (1942).

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CLIMATE AND HEALTH

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During the greater part of geologic time, we are informed, the climate around the whole earth had been milder than it is to-day. Thus the contrasts between summer and winter were less marked, also there were fewer storms with less snow and hail. Climatologically speaking these periods lasting millions of years are usually referred to as "normal" times coinciding as they did with greater geniality and uniformity. From time to time however these immense stretches of comparative peace and quietness were interrupted by brief intervals of violence and revolution characterized by unrest and upheaval in the earth's crust as indicated by the appearance of earthquakes and volcanoes, the formation of high mountains, deserts and a retreat of the oceans. Moreover these revolutions were accompanied by the formation of ice caps in the polar zones with the ice at times extending down to the warmer parts of the earth. It is during the most recent of these comparatively brief glacial epochs that man made his advent upon the earth. Consequently, as Russell pointed out in a recent publication, mankind has never experienced the climatic geniality or monotony of so-called "normal" times which extended over the long interglacial periods, but instead, has continuously been subjected to glacial climates. What the ultimate causes are for these crustal revolutions or the formation of the ice zones are matters as yet unsolved. Nevertheless there is good evidence that the existence of the polar ice cap together with the size and elevation of continents constitute the main determining factors as far as climate is concerned.

From information gained as a result of great scientific advancement and keen observation we know that at present there is a recession in the polar ice cap and that we are passing through a slow amelioration of the severe glacial climates thus far experienced. Whether this recession is likely to be permanent and also its possible extent again form matters for conjecture only. Similarly there is no proof that climatic fluctuations during the brief period of human experience can be interpreted on the basis of recurrent cycles.

Rather does it appear to be a matter of chance in which climatic variation itself determines the type of climate. In any case whatever the underlying factors may be, present day climatic conditions constitute an all important testing out time for the various forms of life which in the struggle for existence either have to adapt themselves to new conditions as they arise or suffer extinction.

The fact that man has been able to establish himself under such widely differing climatic conditions ranging from the cold arctic regions to the moist heat of the tropics implies at first sight truly remarkable powers of adaptation of his body to climatic extremes, a degree of adaptation apparently far greater than that enjoyed by any other animal or plant. The problem of climatic adjustment in man is however an exceedingly complicated matter depending as it does not only on the type and limits of body reaction but largely also on his social and cultural habits by which means he has been able to forestall many of the hazards inherent in climate. Thus Johnston and Martin in a publication in 1841 conclude "for the power of climatic accommodation man is more indebted to the ingenuity of his mind than to the pliability of his body." Apart from the effects of suitable clothing and housing in neutralizing the consequences of an adverse climate, the role assumed by adequate food reserves as well as the application of modern methods of preventive medicine and sanitation may be of even greater significance. That climate, nutrition and specific disease carrying agencies constitute the three most vital factors in the environment of any animal or plant is a matter generally accepted. With regard to the relative significance of each of these factors under the varying conditions of life there is however much ignorance and the greatest divergence in opinion. This is particularly well illustrated by the evidence or lack of evidence concerning the effects of a tropical climate especially on Europeans where the extent of malnutrition, incidence of parasite disease, poor housing and other adverse social conditions may be such that no true perspective can possibly be gained in regard to the primary significance of climate itself. For these reasons bioclimatological research on man is bound to remain an arduous undertaking beset with many pitfalls. Nevertheless there are signs at present that this subject is rapidly forcing itself ahead now that the mysteries concerning the other two environmental factors, namely those pertaining to the cause and prevention of specific diseases and the significance of nutrition have been so brilliantly elucidated within recent times.

Although we are as yet poorly acquainted with the biological effects exerted by climate, i.e. by the sum total of the different factors constituting it, considerable knowledge has, however, been gained in regard to the reactions pro-

duced by such individual factors as variation in temperature and altitude, a brief survey of which may not be out of place here.

PHYSIOLOGICAL RESPONSE TO TEMPERATURE AND ALTITUDE.

Warm blood or homoiothermic animals in contrast to cold blooded or poikilothermic species are capable of maintaining their body temperatures at a very even keel in spite of wide variations in environmental temperatures to which they are exposed. With excessively cold weather, however, certain species of homoiothermic animals such as the hedgehog may turn poikilothermic, thereby allowing its own temperature to fluctuate with that of its environment during the period of hibernation. Through the development of an elaborate heat regulating device the majority of mammals and birds are capable of accurately balancing their heat loss with their heat production thus ensuring a remarkable constancy of body temperature. With the oxidative processes constantly occurring within the living body considerable amounts of heat are being liberated, the actual levels of production fluctuating closely with the degree of activity of the protoplasm. Likewise variable amounts of heat, mainly in the form of solar energy may be impinging upon the outer surfaces of the body thereby tending to alter its temperature. In order to maintain its balance sheet, the body loses heat primarily by radiation, conduction, and convection from the skin which together may amount to approximately three-fourths of the total heat lost under conditions of rest and a mild environmental temperature. The remaining one-fourth is lost mainly through the vaporization of water from the skin and lungs and is usually referred to as insensible water loss. With a rise in the external temperature above that of the body, heat loss through radiation is stopped, thus necessitating the evaporation of more water to produce the desired cooling effect. Similarly vigorous muscular exercise accompanied by the formation of extra large quantities of heat which require prompt dissipation from the body calls forth even greater evaporation of water. This extra amount of water is supplied mainly through the secretion of a specific fluid, sweat, which is derived from the sweat glands in the skin. It is in this respect that important differences are to be noted in the various groups of mammals. Thus it is only in man himself and in Equidae, e.g. horse and donkey, that we can establish well developed sweat glands, widely distributed over the body and endowed with great functional efficiency. In all other species as far as our knowledge at present extends sweat glands, and thereby the mechanism for sweating are either absent as e.g. in the rabbit and rat or but poorly developed and of doubtful significance as is

the case in bovines, sheep, pigs and canines. In order to compensate for this deficiency these animals develop a heat polypnoea under excessive external temperatures, with shallow and rapid respirations. This ensures the evaporation of considerable amounts of water from their moist respiratory surfaces without seriously disturbing the normal gaseous components of the blood. This is particularly well illustrated in the case of the dog which through the familiar signs of panting is capable of evaporating sufficiently large volumes of water from its mouth, tongue and respiratory passages so as to maintain a normal body temperature in the face of widely fluctuating climatic conditions and in spite of the absence of a functioning sweat mechanism. By these subtle means it is capable of accompanying its master, to the outposts of the earth. As indicated by Dukes, the fact that carnivora are better able to regulate against overheating as compared with herbivorous animals is probably associated with lesser mobility in their water reserves in the case of herbivora which thereby are forced to depend very largely on radiation and conduction for their heat loss.

The extent and rapidity with which heat is radiated from the skin depends primarily on the state of the cutaneous circulation and the amount of blood circulating through it at any given moment. Through the presence of so-called vasomotor centres in the medulla oblongata and spinal cord integrated by an acutely sensitive heat regulating mechanism situated in the hypothalamus, the blood capillaries in the skin and subcutaneous tissues can fluctuate between a state of maximal vasodilatation, in which large quantities of blood are constantly being brought up from the interior of the body to the outer surface of the skin and one of marked vasoconstriction during which only the minutest amounts of blood are allowed to reach the skin. By means of this mass shifting of a large volume of blood either to or from the skin under accurate control from the central nervous system, the rate of heat loss can be varied according to circumstances. In this respect the presence of any type of protective skin covering, be it in the form of clothes or natural appendages, decreases the speed with which the heat is being dissipated. Following the drop of the external temperature beyond a certain level referred to as the critical temperature, the body responds by increasing its metabolic rate and thus also the amount of heat produced. This is initiated either by the process of shivering or by any other form of more deliberate muscular activity. According to the work of Cannon and his collaborators there is evidence that the rapid increase in heat production following exposure of the body to a cold environment is associated with greater activity of the sympathetic nervous system and an increased output of adrenaline into the blood. Likewise the secretion of

thyroxine from the thyroid becomes enhanced, only at a slower rate. In addition to the part played by adrenals and thyroids in temperature control the possibility exists that other endocrine organs are also actively associated in this process. Thus the anterior lobe of the pituitary as is now known exerts a dominating influence over all the metabolic processes in the body.

From this brief discussion of the physiology of heat regulation it will be noted that warm-blooded animals, through the possession of highly specialized thermostatic equipment, are in a position to maintain a steady state in their body temperature in spite of wide fluctuations in the amount of heat liberated either within the body itself or as a result of that reaching it from the atmosphere. In respect to the one climatic factor, namely, that of temperature, the homoiothermic animal therefore, can within limits, counter any adverse effects that this may exert on its normal body function. The significance of this fact is, however, immediately qualified by various intercurrent considerations pertaining to species, race, constitution, age, adaptation, state of health and nutrition only, to mention a few of the factors capable of influencing this concept of inherent homoiothermism.

With regard to the biological effects of altitude it has been proved that exposure to reduced atmospheric pressures as encountered on high mountains and plateaux provoke functional changes in the heart and circulation as well as in the nature of respiration. Moreover the accompanying decreased oxygen saturation of the blood through its stimulating effect on the blood forming tissues calls forth a rapid increase both in the number of circulating red corpuscles as well as in the total amount of haemoglobin, thereby restoring an adequate oxygen carrying capacity to the blood.

EFFECT OF CLIMATE ON THE HEALTH OF MAN.

Apart from a few well-known conditions such as sunburn, heat stroke, heat cramps, frost bite, and mountain sickness, we do not as yet know about any specific disease states directly attributable to one or more climatic forces. Nevertheless it is common experience that a change in the weather or a change from one climate to another is definitely associated with a sense of well being as expressed in our physical, emotional and mental reactions. According to the views of Mills, Stone, Hirsch and other observers, the nature of these reactions is determined not so much by the intensity of any climatic factor as by its duration. Thus frequent climatic changes, unless they are of an extreme nature, exert a stimulating effect both on mind and body, thereby maintaining tone and a high degree of adaptability without

imposing undue strain on the different organ systems. In more monotonous climates on the other hand as experienced in tropical regions, both the diurnal and the seasonal fluctuations in temperature and humidity remain confined within very narrow limits. In the absence of climatic stimulation both the tone and the range in adaptability of the body become decreased. Consequently there may be greater sensitivity to abnormal weather conditions, e.g. a sudden cold spell which is usually associated with the familiar tropical "chill." Combined with poor social and economic conditions this in turn predisposes towards the contraction of such pulmonary diseases as pneumonia and tuberculosis. To compensate for the inadequacy of the climate in providing the much needed stimulation, recourse is frequently sought in alcohol to act as its substitute—a step which on physiological grounds can only help to sensitize further an already sensitized body.

Although a monotonous climate tends to limit the degree of body adaptability, varying degrees of "acclimatization" may nevertheless be experienced. The physiological basis underlying the process of acclimatization is, however, as yet by no means fully understood due to the complicating effects of individual constitution and habits of life. It is however known that under tropical conditions the composition and the circulation of the blood may be significantly changed. Thus the extent of the blood flow through the skin may be such that with the accompanying vasodilation the general blood pressure is inclined to be lowered. In order to satisfy the requirements of the remaining body tissues the blood volume is increased. The greater wateriness of the blood in turn facilitates sweating. Undue loss of water and mineral matter, especially sodium chloride, in the sweat frequently results in muscular exhaustion and digestive disturbances. These effects can, however, be largely evaded by a suitable diet and a liberal intake of water and salt. In this respect acclimatization involves the training of the sweat glands to secrete a more diluted sweat thus conserving more valuable salt in the body. This constitutes an exceedingly important matter since undue lowering of the inorganic blood constituents, especially of the different chlorides immediately causes a disturbance in the osmotic equilibrium existing between the blood plasma and the tissue fluids and hence in the water balance of the body as a whole. In the opinion of Stone, the effects of continued sweating in man on the chemical composition of his blood may constitute an important cause in lowering his resistance to infection. Moreover the condition of heat cramp can be definitely associated with insufficient sodium chloride in the body and thus the regular intake of salt and water prevents the onset of the characteristic symptoms. Whether the basal metabolism

undergoes a definite change in the tropics is as yet an undecided problem due largely to the complications arising from altered food supplies as well as possible deviations in the functions of the endocrine system and the sweat glands.

Acclimatization to a hot environment does however involve a lower heat production by the body and consequently also a lower output of energy. Subsequent change over to a cold climate frequently finds the individual slow and sluggish in his reactions to abrupt weather changes and therefore subject to chills and rheumatoid conditions. In the final instance, however, the speed and degree of adjustment remains an individual matter based largely on constitution and therefore on such vital considerations as those of endocrine balance and efficiency of the autonomic system. Passage from a cold to a hot environment is frequently associated with acute discomfort as marked by great susceptibility to heat exhaustion and even heat stroke. This is due largely to a temporary continuation in the high level of heat normally produced under colder conditions. As acclimatization sets in heat production is reduced, while the cutaneous circulation becomes adjusted so as to increase the blood flow to the skin and sweat glands. This means that the "comfort zone" has been shifted in such a manner as to enable the normal physiological processes to continue without the imposition of undue strain.

Concerning the other biological effects of solar radiation very little has as yet been scientifically established. The development of the familiar "tan" against the ultra violet fraction in sunlight exerts an important protective action against permanent skin damage which otherwise would follow prolonged exposures. Although ultra violet therapy is widely used in the treatment of tuberculosis it is interesting to note that this disease is very prevalent throughout the tropics in spite of a superabundance of sunlight. From this it appears that poor nutritional and hygienic conditions far outweigh the beneficial effects of sunlight.

Endowed with a strong skin and highly efficient sweat glands the native is fully capable of countering the effects of greater heat absorption which is characteristic of any black surface as compared with a white one. Seeing that sweat reaction is closely associated with the skin temperature, the native sweats more copiously and sooner than the white man does from an equally exposed skin surface.

CLIMATE IN RELATION TO THE HEALTH OF FARM ANIMALS.

As is the case in man our knowledge concerning the direct effects of climatic forces on the bodies of animals is still very meagre. Apart from a few specific conditions such as photosensitisation we are not aware of any characteristic

diseases directly associated with the climate. On the other hand there exists no doubt that climate through its effects on vegetation and thus on the food supplies of all herbivorous animals has an indirect though none the less profound bearing on the health and production of all livestock throughout the world. Seeing therefore that nutrition, which in itself constitutes an environmental factor of primary importance is subject to such wide fluctuations it becomes an exceedingly difficult matter to assess the direct significance of climate on any animal unless its plane of nutrition is rigidly controlled and thus all intercurrent disturbances due to malnutrition as well as to other specific causes excluded. Unless this aspect of the problem receives full consideration it is felt that the results of bioclimatological research work on animals will tend to remain inconclusive. Where a high plane of nutrition has been maintained there is evidence to show that such factors as butterfat and egg production are influenced by seasonal changes. In this connection Regan and Richardson record a sharp drop in the milk yield of cows on a rise in temperature from 40° F. to 95° F. in their environment. Similar findings are reported on by Rhoad and Villegas. Likewise the fertility and breeding season of animals are adversely effected by continued high temperatures. On the other hand increased daylight promotes fertility and egg production.

As a result of extensive investigations conducted mainly on cattle in various countries, distinct differences have been established between breeds in their ability to withstand climatic conditions. In this respect the Zebu types show a degree of adaptability especially to warm climates which is superior to that of other breeds. By taking advantage of this fact the Zebu has been extensively used for crossing mainly with various European beef breeds. By these means animals are obtained in which greater adaptability to a warm climate is combined with more desirable beef qualities. Such cross bred animals according to the findings of Rhoad and others are subject to far smaller fluctuations in their body temperature and respiratory rhythm as compared to pure bred European strains when exposed to sunlight during warm weather. This is accepted as indicating the degree of ease with which body heat can be dissipated from comparative groups. Similarly differences are recorded in the grazing habits of animals thus exposed. By crossing the Shorthorn with a Zebu type a new beef breed termed Santa Gertrudis has been evolved in Texas. Improved dairy types are likewise being produced by judicious crossing. In this respect it is of interest to note that the Jersey breed shows a tolerance to heat greater even than that displayed by some strains of cross bred animals hence the possible value of Jersey blood to dairying in tropical and subtropical countries.

BIOCLIMATOLOGICAL RESEARCH IN SOUTH AFRICA.

South Africa practically as a whole is blessed with a climate which is envied far and wide. Living under remarkably clear skies and a superabundance of bright sunshine we South Africans believe that with rare exceptions both man and his animals could not wish for a better climatic environment. Concerning the effect of this climate on the vegetation of the country we are less happy primarily as a result of the vagaries in the prevailing rainfall and moisture conditions. As indicated in a report by Schumann, South Africa is situated in the high pressure belt of the Southern hemisphere being subjected to a circum-polar low pressure zone. In effect this means that the country is continually being influenced by irregularly occurring high or low pressure disturbances travelling from a westerly to an easterly direction. During the summer season the central part of the country comprised essentially of a high level plateau becomes strongly heated up in consequence of which a low atmospheric pressure is established. Due to existing high pressure along the coast line moisture laden air is swept from the warm ocean into the interior, thereby explaining the occurrence of the summer rainfall. During winter the reverse conditions prevail, the rapid cooling of the land mass being associated with the establishment of a permanent high pressure and a movement of air from the land towards the sea.

In regard to temperature, about which a comprehensive account has recently been published by the Meteorological Department, it is significant that the average annual readings throughout the country fluctuate between the narrow limits of 55° F. (Belfast) to 66° F. (Pietermaritzburg), although at Durban it reaches 70.8° F. The seasonal variations on the other hand may be considerable, ranging up to 29.4° F. at Fraserburg. Likewise the diurnal temperature may fluctuate up to 35° F., being greater in the interior than along the coast. Whereas a comprehensive meteorological service is being maintained within the Union it was only within very recent years that a solar radiation survey was contemplated. Due to the part played by sunlight in the constitution of our climate it was obviously of the greatest importance to collect information on such factors as the amount, quality and distribution of sunlight in different parts of the country. This survey was undertaken by Miss Riemerschmid at six different centres, three being situated inland and three along the coast. Extending over a period of 12 months (1937-1938) continuous records were obtained on the total amount of sun and sky radiation, also of its intensity at any given moment, of the ultra-violet content and of the cooling temperature. Associated with the records on cooling temperature which is of special physiological significance a so-called "scale of

sensation" was included. From a very comprehensive column of data collected, the following represent some of the main conclusions reached:—

- (1) The amount of radiation over the inland centres exceeded that at the coastal stations throughout the year, the highest values over a period of 12 months being recorded at Johannesburg. During the first six months of the investigation the amount of radiation at Cape Town and Port Elizabeth was approximately equal while at Durban it was distinctly less.
- (2) In a comparison of the radiation at Johannesburg, Nairobi, Davos and Bad Neuheim, it is revealed that the amount of radiation at Johannesburg during winter was much greater than at Davos (Switzerland) or Bad Neuheim due principally to the high altitude of the sun and the clearness of the winter season at Johannesburg. Physiologically this difference in winter radiation is important since it is associated with a period of rest in the life of many plants and animals. The amount of radiation at Nairobi on the other hand was found to be greater than at any of the other abovenamed centres.
- (3) The diurnal variation in the cooling temperature was greatest at the inland centres, this being more marked at Johannesburg than at Bloemfontein or Nelspoort. The average conditions at the coastal stations on the other hand showed no distinct differences.
- (4) Whereas a rapid decrease in the cooling temperature at the inland centres was continued after sunset, this drop became much smaller at the coastal stations.
- (5) The monthly average cooling temperature in winter was distinctly lower at the inland centres although in summer this difference was not so pronounced.
- (6) On the scale of sensation no distinct difference was found between the inland and the coastal centres as regards the frequency of the various ranges.

Thus at each of the 6 localities exposure to the sun for at least 60% of the time during daylight should be withstood without the imposition of much physiological strain. The effect of overcooling through the preponderance of "cool" over "hot" hours was greater than that of overheating.

In regard to the influence of climate on animal life in South Africa research work has thus far been confined largely to cattle. With the objects of studying the reactions of different pure breeds as well as cross bred bovines to environmental conditions while grazing on the open veld, a series of long term experiments have been in progress at Armoedsvlakte in Bechuanaland, as well as at Messina and Mara in

the Northern Transvaal. From the large volume of data collected in these experiments both Bisschop working at Armoedsvlakte as well as Bonsma at Messina and Mara have been able to demonstrate a definite regression in several of the well-known European beef breeds as compared either with an indigenous breed such as the Afrikander or with cross bred animals. This difference is expressed primarily in such factors as conformation, rate of growth, bone and muscular development. In order to understand the physiological basis underlying these differences in body response a further series of observations and measurements were included in the experimental work. These included data on fertility and reproduction, blood studies, pulse and respiration rate, rectal as well as skin temperature, quality of skin and hair, rate of rumination as well as continuous records on solar radiation and other meteorological phenomena. The main conclusion derived at by Bonsma from work conducted in the Northern Transvaal is that regression in the exotic breeds is due primarily to their decreased ability in controlling body temperature especially during the warm season, this being associated with well defined differences in skin and hair development. The interpretation of the other findings are all based on this conclusion.

In regard to the work at Armoedsvlakte the interpretation of the data will depend on the outcome of statistical analysis now in progress.

Although it is unnecessary to stress the importance of this work, viz., to develop a useful type of animal fully adapted to its environment on the South African veld it should be emphasized that the various experiment stations are all situated in areas subject to periodic and even severe drought conditions. Consequently the state and amount of the vegetation and with it the nutritional plane of the animals are exposed to wide and uncontrolled fluctuations. The probability therefore arises that the primary effects of climate on animals, whatever this may be, is constantly being masked by a change in the level of nutrition.

In order to gain further information in regard to the more direct effects of climate on animals as well as on the physiological processes associated either with acclimatization or degeneration it appears essential that the following factors should receive due consideration:—

- (1) Controlled exposure of selected groups of animals of different breeds preferably from the time of birth, (a) to identical climatic conditions and (b) to climatic conditions in different localities selected on the basis of contrast, while the various climatic forces are being measured as fully as possible.

- (2) Controlled level of nutrition by ensuring a food supply of identical quality and amount to all animals in comparative tests.
- (3) Application of identical hygienic measures in preventing intercurrent disease conditions.
- (4) Control of energy output by restricting movement to within the same limits.

Having standardized the experimental conditions, differences in body response can be measured in numerous ways, some of which are included in the work conducted at each of the abovenamed centres. In order to interpret the physiological significance of any data obtained, a prerequisite of primary importance includes a comparative study in metabolism which has hitherto been badly neglected in bioclimatological work. This study should include balance experiments in which food and water intake is compared with excretion of urine and faeces, thus providing valuable data on the digestion coefficient of different animals. Similarly a study on basal metabolism and energy balance is essential to an understanding of heat production within the body and thus to the processes of climatic adaptation. In this respect the respiratory exchange, i.e. the determination of the oxygen consumption against the carbon dioxide production referred to as the respiratory quotient should also be investigated. Likewise studies on blood chemistry and morphology, as well as of skin structure, cutaneous circulation, sweat gland development together with the work on metabolism are all essential in the interpretation on a physiological basis of such factors as growth and development, reproduction, cardiac and respiratory rhythm and body temperature. Due to the differences in sweat secretion between man and animals, and thus of the cooling effects of the evaporation of water on the skin, emphasis should be laid on investigations relating to the water balance of the body as well as on the extent and significance of insensible water loss through the skin and respiratory tract, the phenomenon of heat polypnoea, radiation and conduction of heat in relation to skin colour and hair development. In conjunction with the bioclimatological studies on cattle more attention should be devoted to sheep especially the Merino, an animal of great economic significance to South Africa. In spite of its thick wool covering this exotic breed has adapted itself remarkably well to the high temperatures on the South African veld, thereby comparing very favourably with the indigenous Afrikander breed. From investigations conducted recently by Rousseau and others on the by-products of wool, it has been revealed that remarkably high amounts of potassium mainly in the form of carbonate are secreted by the Merino skin, while the

sodium content unlike the case in normal human sweat is negligible. The significance of these findings especially in so far as these effect skin function and wool growth has yet to be explained.

In order to supplement bioclimatological research work already in progress, Murray and Quin recently initiated a long term investigation in which the closely inbred Wistar strain of white rats is being used as the test animal. Although no final deductions can as yet be made from this work, differences have already been established in the level of food and water consumption and rate of growth between comparable groups of animals when subjected either to daily exposure of sunlight or to continuous sheltering. In order to ascertain the significance of the nutritional factor on reaction to a climatic force, in this case sunlight, the quality of the food is strictly standardized throughout. Moreover two planes of nutrition are being maintained in which some groups are being adequately fed while in others the food intake is restricted. Contrary to expectation, it has been revealed that the new-born albino rat, despite the absence of skin pigment and hair, can withstand prolonged daily exposure to direct sunlight without developing any of the familiar signs of sunburn, thus exhibiting a high degree of resistance to the harmful effects of short wave actinic radiation. On the other hand it shows greater susceptibility to the long wave heat rays which in excessive amount lead to exhaustion and finally to heatstroke associated with cerebral haemorrhage and rectal temperatures above 110° F. Repeated exposure of young animals in which incomplete functioning of the heat regulating mechanism leads to a rapid and excessive rise in body temperature, is frequently associated also with continued diarrhoea and loss of water from the body. To what extent this may be related to summer diarrhoea as seen in children and other young animals is a point which merits investigation. There are indications also of differences in the age of sexual maturity of animals in the various groups.

Due to the ease in handling as well as to its uniformity and ready response, the albino rat is a mammal which may prove to be extremely useful in bioclimatological research work. For these reasons further experiments are under way in which comparable groups of young animals kept on an identical diet are to be distributed to selected centres throughout South Africa where such factors as growth, fertility, food and water consumption are to be studied under different climatic conditions, while exposure, hygiene and general care are to be rigidly standardized. A similar type of research programme is to be undertaken on Merino sheep, commencing with newborn lambs.

CONCLUSION.

An attempt has been made to draw attention to the problem of climate about which as far as its more direct effects on the health of man and animals is concerned, precious little is as yet known. Nevertheless the successful migration of all forms of animal life has been constantly subjected to the dominating influences of climatic forces. Despite his wide powers of adaptation, civilized man has hitherto selected only the more hospitable climates for his permanent abode avoiding alike both arctic and tropical environments. Associated with overcrowding and consequent intolerance there are however definite signs that human migration to lands of lesser climatic hospitality may soon be a matter of dire necessity. Without knowledge concerning the biological effects of climatic extremes, any such migration might be attended by serious human regression.

As far as South Africa is concerned, we believe, in the absence of any concrete evidence to the contrary, that both man and animal are placed in an ideal climatic environment. On the other hand there is ample evidence to prove that through the presence of man and animals various climatic forces have been allowed to play havoc with the land and its natural vegetal covering, the consequence of which may be such as to throw into the balance the whole undertaking of a European civilization in this Southern portion of Africa. Despite its youth the country is already showing many of the scars of old age. In turn this is unmistakably being reflected on both its human and animal population, a large proportion of which is rapidly drifting to the wall. Our environment at present is obviously not such as to support a flourishing community. What exactly the nature and extent of the deficiencies are, whether they be due to the climate, or to inherent poverty of the soil, to constant contact with indigenous races or to the lack of contact with European culture, to an unjust social and economic system, to inherent blindness or simple complacency, all this we do not know.

In common with all those shaping the future destiny of this vast continent, it is obvious however, that we too in South Africa are singularly lacking in our appreciation of the African environment with its apparent potentialities and even greater limitations. To the uninitiated it presents a picture of vast possibilities whereas in reality it is but a tender flower wilting at the first turn under an unkind heel. Not only are we strange to each other but even more strange to an environment which we choose to call "home." Through stress, following a serious conflict with Nature we are now hopefully turning our eyes to a future era of industrial expansion in South Africa despite

the lesson so forcibly being learnt to-day by industrialized Britain that a sound land and agricultural policy still remains the *sine qua non* for any form of communal endeavour. With our mining instincts deeply engraved and diversely applied, we are being seriously challenged as to the soundness of any contemplated step, more so as a result of past mistakes and the impressions left behind. Any further continuation of the numerous soil exhausting practices, although providing as they do for such an integral part of present day international trade, can only mean greater vulnerability to climatic and other natural forces and will therefore lead to a further aggravation of the threat to our national existence.

As scientists interested in the future welfare of South Africa, our greatest duty lies in the intensification of the study of our typically African environment of which climate constitutes by no means the least important part. Without all this essential store of knowledge it is obviously impossible to harmonize with Nature and therefore to ensure the ultimate success of our long term experiment, namely, to prove that a European culture and civilization can turn the African continent, at least in part, into its own home, permanent and flourishing.

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SOME PROBLEMS OF THE STONE AGE IN SOUTH AFRICA

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Presidential Address to Section E, Read 30th June, 1942

Prehistoric Archaeology is not one of those sciences which receives a stimulus from war conditions. It has no contribution to offer to the arts of war.

It is true that, as Graham Clark (1939) has pointed out, during the last Great War military activity on both sides and particularly trench warfare did lead to discoveries of archaeological value, but such discoveries were incidental, and their proper investigation had to be subordinated to military exigencies. Perhaps the most valuable contribution which war has made to archaeology has been the development of the technique and application of air photography, but the fruits of this can only be reaped after the cessation of hostilities. On the whole there is no doubt that the work of the prehistorian is hampered and not advanced by modern war. Everywhere the interests of such studies have been taken from the workroom and placed temporarily in the store-room. This is therefore not the time to attempt to pass in review the recent achievements and progress of our science. I have felt, however, that the time is appropriate to take stock of our present position and to consider some of the problems which face us to-day. It is both necessary and salutary to abandon the complacent contemplation of our achievements and to attempt to see clearly what we are trying to achieve.

I cannot, of course, attempt here to deal with more than a few of our problems or to treat of any one of them exhaustively. I shall therefore mention only those which I feel are the most important and urgent, the solution of which would contribute most directly to immediate progress in our science.

At the very outset of our studies we are faced with one of our biggest problems. When did man first appear in South Africa? Wayland as long ago as 1922 first collected, and in 1929 described a pre-Stellenbosch (pre-Palaeolithic) pebble culture from Belfast in the Transvaal. Subsequent examination of the site by van Riet Lowe revealed that the

horizon from which the specimens came is that on which Middle Stone Age types are commonly found, and examination of the type specimens which are housed in the museum of the Bureau of Archaeology throws further doubt on the validity of Wayland's interpretation. McFarlane (1935) has described pre-Stellenbosch types from East London. J. C. Smuts (Jnr.) (1938) on scanty evidence collected at Benoni and near Pretoria, has claimed to have established no less than seven successive Cultures preceding the Stellenbosch Culture in time as well as in cultural development. These he correlates in detail with climatic fluctuations which take us far back into Pliocene times. However, these conclusions have not found general acceptance. Even the pre-Stellenbosch pebble culture of the Vaal river basin is still open to some doubt, as it occurs on the surface of the Older Gravels and is covered only by Kalahari sands which may not have sealed them at all times, though the recovery of heavily rolled specimens from the earliest aggradations of the Younger Gravels is significant.

The precise geological background of the Stellenbosch culture of the Cape is still unknown. The earliest manifestations of the Stellenbosch culture, whether it be the Cape expression or that found in the Vaal river basin, is already a well-formed, crystallised culture which must logically be rooted in something which preceded it, yet we have nowhere in South Africa found undisputed evidence of those roots. It is easy to beg the question by suggesting that the Stellenbosch underwent its earliest evolution somewhere in Africa outside the Union, but that is no solution to our problem.

Prehistory in South Africa, as a systematic study, may be said to have begun with the conference held in Pretoria under the auspices of this Association in 1926. From that conference emerged much of the system which to-day forms the basis of our study. Before that time, beginning with the work of Sir Langham Dale in the seventies of last century, much good preliminary work was done, but there was no co-ordination, and but little understanding, between those who interested themselves in this field of study. Goodwin (1935) has shown that this early work resolved itself into two main schools of thought; the one ascribed all archaeological finds to an undefined people called the "Bushman," while the other, headed by Johnson and Peringuey, emphasised typological parallels with European prehistoric cultures, and championed the so-called diffusionistic view that from Africa came nothing which did not have its source in Europe. The Pretoria conference of 1926 realised the dangers of premature long-distance correlations and gave us a new and independent terminology. While the degree in which that terminology is still valid to-day is a measure of the far-sightedness of those who evolved it, the degree in which it has been modified,

or requires modification, is a measure of the virility of the science and the progress that has been made. Many changes have in fact been introduced, the most notable one being the recognition of that interesting and complicated group of cultures which flourished during the Middle Stone Age.

In his Presidential Address to the Royal Anthropological Institute in 1940, Prof. Radcliffe Brown summed up the present state of terminology in Social Anthropology in the following words :

“ The choice of terms and their definitions is a matter of scientific convenience, but one of the characteristics of a science as soon as it has passed the first formative period is the existence of technical terms which are used in the same precise meaning by all the students of that science. By this test, I regret to say Social Anthropology reveals itself as not yet a formed science. One has therefore to select for oneself, for certain terms, definitions which seem to be the most convenient for the purposes of scientific analysis.”

If this is true for Social Anthropology with its more voluminous and mature literature, how much truer it is for the science of Prehistoric Archaeology in general and in South Africa in particular. This difficulty is not confined to South Africa; Huzayyin (1941), discussing the possibility of applying European terms to Egypt, complains that

“ until the time has come when a general agreement is possible no author can do more than make clear the exact meaning and connotation of the terms he uses.”

Although the 1926 terminology has lent itself so well to development and adaptation, the need for a further conference is becoming increasingly felt. Neville Jones has already taken the initiative in this. At his suggestion in 1939 the South African Museums Association arranged an informal discussion in Bulawayo, as a result of which that body resolved to request this Association to convene a new conference at which problems of terminology may be discussed.

The most important principle adopted at the 1926 conference was the recognition of the need for a terminology for South African cultures independent of the classical European terminology, giving rise to such purely South African names as the Stellenbosch, Still Bay or Wilton cultures. This emphasised the differences between the South African and European typologically related cultures, and the impossibility of inter-continental correlation. Van Riet Lowe (1937) in an appendix to his paper on the Vaal river

survey, basing his view on extensive travels throughout Africa, has advocated that a measure of correlation, at any rate between the Earlier Stone Age of Africa and the Lower Palaeolithic of Europe is now warranted, and urged the use of the classic term Acheulean, qualified by a regional prefix, to indicate the essential affinities and at the same time to make allowance for regional differences. We should then speak of the South African Acheulean, the Kenya Acheulean or the French Acheulean.

Apart from cultural terms, we require terms to denote special techniques used in the manufacture of stone implements. The distinction between cultural terms and terms denoting a technique is basic, but has not always been recognised. It is the more easily lost sight of because in Europe the same term is often applied to a culture and to a technique. The convenience of a single term to describe a complicated process is at once evident, but such terms should be clearly divorced from any cultural meaning. It is legitimate, for instance, to apply the term Levallois to the technique employed in South Africa during Middle Stone Age times, provided that no cultural identity with the Levallois of Europe is implied. How widespread a need for greater clarity is, has more recently been evidenced by the correspondence in *Man* (1936) initiated by Burkitt working in England, and responded to by O'Brien who worked in Uganda and by van Riet Lowe. Burkitt warns us against the use of European terms for "foreign" cultures; O'Brien admits the dangers but urges that

"it would be more convenient to retain original names for cultures that are, in the sum of their characters, really like the proto-type; and then, if necessary, to tack on local or industrial or technical (i.e. descriptive) appellations—in other words, genus—species."

In this view, O'Brien is supported by van Riet Lowe who urges in addition the application of European terms denoting techniques to identical processes outside the western European region.

This is not the occasion to discuss the merits of such suggestions. That can only be done at another conference the need for which Neville Jones has stressed.

Mention of the Vaal river survey leads me to another urgent problem in our subject. The elucidation of the recent climatic history of the Vaal river basin and the correlation of the stone cultures of that area with the climatic changes, has been one of the major strides in the progress of our knowledge, but it has served to emphasise the absence of any knowledge of the prehistoric climatic background elsewhere in the Union. The events in the Vaal river area were

on such a scale as to leave no doubt that they cannot have been mere localised phenomena, a conclusion which is borne out by the work of Cooke and Clark (1939) on the deposits of the Zambezi river at the Victoria Falls. Their results are analogous but not identical with those found in the Vaal river basin, and serve to bring home to us the dangers of assuming too wide a geographical extension of the climatic sequence established for any particular confined geographical area.

Historically, the most important of our South African stone age cultures is the Stellenbosch of the Southern Mountain region, yet it has been studied from a typological and technical point of view only. On such grounds, and on the general principle that so widespread and prolific a culture must have undergone a progressive development, three stages as yet only vaguely differentiated, have been recognised. Peringuey's type site at Bosman's Crossing undoubtedly yields material which is typologically cruder and presumably earlier than that which F. Malan (1939) of Wellington has so meticulously described from the Wagenmakers Vallei. The Fauresmith Culture has never been recognised in the Western Province. The most advanced elements of the Cape Stellenbosch are technically and sometimes typologically not very remote from the Fauresmith, and further research on the Cape Stellenbosch with particular reference to the influence of material to hand, might well reveal to us the equivalent of the Fauresmith in that area. This lack of a reliable stratigraphical analysis of the Cape Stellenbosch strikes at the very root of our understanding of the Earlier Stone Age, yet the solution is probably offered by the terraces and gravels of the Berg river and its tributaries. An archaeological survey of this area is long overdue and when it is undertaken by a party of geologists and archaeologists working together as was done in the case of the Vaal river survey it is safe to prophesy that a flood of new light will be thrown on many of our problems.

It would be a serious omission not to recall the early work of Shand (1913) who nearly thirty years ago studied and reported on the terraces of the Eerste River at Stellenbosch. It is true that he ascribes the formation of these terraces not to climatic changes but, after discussing the effect of a number of purely geological circumstances, he concludes

"we must therefore fall back upon general elevation of the country as the only phenomenon which is fully competent to afford the stimulus by virtue of which the river was enabled to lower its bed and to erode where it formerly aggrated."

This general elevation of the country Shand correlates with the shelf surrounding Signal Hill and another at Hermanus and makes the interesting remark

"with this evidence before us there is no reason why one should hesitate any longer to admit that in comparatively recent times the isthmus which connects the Cape Peninsula to the mainland was submerged, and the Peninsula itself divided into a pair of islands."

The drainage area of the Berg river is separated from that of the Eerste river only by the Jonkershoek mountains near Stellenbosch. If Shand's explanation is correct, it is therefore likely that the terraces of the Berg river are also to be associated with sub-continental tectonic movements rather than with significant climatic changes. In that case we cannot look to these rivers for a correlation of climatic events with the Vaal river basin, but an archaeological investigation of these deposits will nevertheless give us the long-awaited stratigraphical relationships between the various developmental stages of the classic Stellenbosch culture of the Cape.

In passing it is interesting to note that Goodwin in 1933 expressed the view that the final 20 ft. minor emergence took place when the Still Bay and Howieson's Poort cultures had already developed, a conclusion confirmed by Goodwin and Malan (1935) on evidence from the exposed raised beach at Cape St. Blaize, Mossel Bay. On this hypothesis the two islands of the Cape Peninsula were separated from the mainland during Stellenbosch times and the earlier part of the Middle Stone Age, though the occurrence of Stellenbosch material at Cape Point indicates that access across the separating straits could not have been impossible.

This is but one of many areas which offer solutions to some of our stratigraphical problems. Another which would repay the attention of a surface or recent geologist is the Great Fish River. Where the road from Grahamstown to Fort Beaufort crosses the river a series of deposits were observed which bear a very close superficial resemblance to those of the Vaal. Both van Riet Lowe (1938) and Cooke (1941) have drawn attention to this site. Cooke goes so far as to say:

"Except for the absence of the Middle Stone Age horizon, between the Fauresmith and the Later Stone Age, this deposit bears a remarkable resemblance to many sections in the Vaal river basin, and the same general climatic sequence may be inferred, subject to a wider examination."

One of the striking features of the Earlier Stone Age in South Africa as we know it to-day is the consistent occurrence of core and flake tools combining to form integral features of the same culture. The parallel and culturally distinct development of core cultures and flake cultures during the Lower Palaeolithic has become a commonplace in European prehistory, and has been found also in Kenya and Uganda. Van Riet Lowe explains this by postulating that a fusion of the two technical traditions took place somewhere in Africa before these cultures penetrated southward into the Union. Such a theory precludes the possibility of direct local development from such cultures as the Pre-Stellenbosch of the Vaal river basin which is a pure core (pebble) culture, to the first manifestation of the true Stellenbosch culture as we see it at Vereeniging. Van Hoepen finds van Riet Lowe's hypothesis of fusion outside the Union untenable on other grounds and in his Presidential Address to Section E of this Association (1938) announced that he had found a pure flake culture of the Early Stone Age which would be described after further work on the site. Unfortunately the site was believed to be devoid of stratification, so that it will perhaps be difficult to convince the sceptic by means of this evidence.

When we come to consider the Fauresmith culture, its distribution and the possibility of this culture being recognised over a wider area, the importance of the materials available becomes very marked. Fauresmith industries as we know them in the Orange Free State and the northern Cape are made up almost entirely of indurated shale, with the strange exception of one tool type, the cleaver. The same typical Fauresmith processes of manufacture when applied, for instance, to the quartzite of the Southern Mountain region, might well give a different result. There is some evidence for this from a site on the Bushmans River, where we have found an industry which can only be described as an advanced variation of the Fauresmith, modified by the use of water-worn pebbles of quartzite. An even more problematical industry has been described by Cramb (1935, 1937) from the mouth of the Tugela river which also may yet prove to be the work of Fauresmith people applied to quartzite.

I have just mentioned the cleaver in the Fauresmith which is itself a minor problem. Most Fauresmith industries in the Vaal river area are made up of indurated shale, but contain numbers of cleavers of Ventersdorp lava which conform in material, technique, type and state of weathering to those of the third, fourth and fifth stages of the Stellenbosch sites. While there is no doubt that Fauresmith man did make his own cleavers, my own view is that he took advantage of the unlimited supply of ready-made cleavers available to him on Stellenbosch sites.

The line of demarcation between the Earlier and the Middle Stone Age was at first believed to be clear-cut. Typologically it was believed that the handaxe was present only in the Earlier Stone Age, and the presence of this tool type in a collection was regarded as proof of the activity of Earlier Stone Age people. This we now know to be unsound. Handaxes are now recognised, for example, in the Pietersburg Culture of the Middle Stone Age. The recognition of the Fauresmith Culture with its integral combination of handaxe and Levallois types has further bridged the gap. On typological and technical grounds it is now not impossible to postulate a purely South African cultural development from the Pre-Stellenbosch to the end of the Middle Stone Age. This hypothesis is considerably strengthened if we see in the Victoria West technique of the third and fourth stages of the Stellenbosch culture of the Vaal river basin a proto-Levallois technique as van Riet Lowe has suggested. It is true that this technique was abandoned during Stellenbosch V times at Riverview Estates and that the true Levallois appears as something new after the long arid period which preceded the development of the Fauresmith culture in that area. It is still an open problem whether the Levallois technique of the Fauresmith owes its origin to a revival and development of the forgotten Victoria West tradition or to the appearance of a new influence from the north, possibly as a result of a new migration.

This question of the origin of the Levallois technique in South Africa is at present one of our insoluble problems. It is not unlikely that its eventual solution will depend on the work of the physical anthropologist rather than on that of the prehistorian. It is not unreasonable to hope that we shall one day find skeletal remains of the men who wielded the Victoria West technique and of those who enjoyed the Fauresmith culture. When physical anthropologists have agreed on the correct interpretation of this material yet to be discovered, and the remains of the men who wielded the Levallois technique of the Middle Stone Age, we may hope for light on the origin of the Levallois technique in South Africa. I will not be accused of undue pessimism if I say that this solution is as yet extremely remote. The lack of agreement between physical anthropologists on material now known is such that it cannot but discourage the archaeologists' hopes of assistance from that direction. While there is room for such divergent authoritative views as those of Dart and Broom the archaeologist must needs go his own way and wait patiently for future developments.

Of the Middle Stone Age we still know regrettably little, and the tendency in recent years has been for the position to become more confused. During this period of time there flourished in South Africa a number of cultures and

specialisations or "variations" of those cultures, some of them certainly contemporaneous. A few caves have been excavated and these have yielded valuable stratigraphical sequences, as for example the Peers Cave and Cape St. Blaize Cave, but much more cave excavation remains to be done. The interrupted work of the late Messrs. V. and B. Peers has never been completed, and many of us await with interest the revelations of the lower deposits in the Peers Cave at Fish Hoek.

For a full understanding of the Middle Stone Age the mere description of more and more variations, while very necessary, will not in itself be effective. If, as we think, many of these variations flourished side by side, we must expect to find that even stratigraphy in cave deposits will fail us, for adjacent caves may well have been occupied by several of these contemporaneous groups in different order. We must expect to find, for example, that in one cave Still Bay implements underlie Mossel Bay, and a reversal of the sequence at another site. Goodwin has suggested that a fruitful approach to the study of Middle Stone Age inter-relationships lies through the study of what he calls "technical themes" running through some and absent from others of the variations. This approach is clearly seen in his general summary (1935). Thus he sees at the beginning of the Middle Stone Age a combination of Levallois and Mousterian influences, and later Mousterian and Capsian influences being evidenced by the increase in the length of the flakes, the partial disappearance of the faceted butt and the appearance of the burin. He continues:

"Meanwhile in the Union itself, relatively pure Middle Palaeolithic types were appearing which had hardly been tainted by 'blade and burin' methods. This latter intrusive element increased until by the time we arrive at the extreme South we appear to have highly evolved contact cultures of Middle Stone Age and Capsian mixture, which follow directly upon the Earlier Stone Age at this point. To such must be credited the developed Levalloisian we know as the Still Bay Culture, superficially resembling the non-Levalloisian Solutrean of Europe in its finer types."

One of the difficulties when considering such an approach is the lack of adequate descriptions of our cultures. Those who first described them would be the first to admit that our knowledge has far outrun their original descriptions. What was described by Goodwin as the Pietersburg Variation, based mainly on a collection from the farm Grace Dieu in the Pietersburg District, is now known to be the basic Middle Stone Age culture of the central Transvaal which passed

through several stages of development locally, and much has been learned of the stratigraphy of nearly thirty sites yielding large collections of tools of this culture. Similarly all that has been published on the *Alexandersfontein Variation* is contained in one printed page, yet we have reason to believe that it, too, is an important culture which flourished over an extensive portion of the centre of the Union. Full descriptions of these and other cultures in their proper geological settings are very necessary and would contribute directly to greater clarity on the problems of the relationships between the many constituent industries of the Middle Stone Age. Indeed the need for a reliable, authoritative and comprehensive text book of South African archaeology has become a very urgent one. Its fulfilment will be a difficult task, for the need is felt as much by the trained worker as by the increasing number of educated members of the general public who are interested in the subject. Only two works of this kind are available at the present; those by Burkitt and by Goodwin and Van Riet Lowe, and both are very much out of date.

While the *Fauresmith* culture seems to form a bridge between the Earlier and the Middle Stone Ages, there is a striking break in the continuity of typological development when we come to the end of the Middle Stone Age. The apparently sudden and complete disappearance of all traces of the *Levallois* tradition which so completely dominated the Middle Stone Age, and the appearance of pure blade cultures in its stead, must have been one of the major cultural revolutions in the prehistory of South Africa. As yet we can offer no explanation of this event. There are, however, some indications which may one day bridge this strange gap in the cultural development. Wayland and Burkitt as long ago as 1932 described the *Magosian* culture from North-East Uganda which seems to present a combination of very advanced *Levallois* (Still Bay) with an archaic *Wilton* containing pygmy tools. Theoretically such a culture is just what one would expect to fill the gap between the Middle Stone Age and the Later Stone Age in South Africa. It is true that the *Magosian* is dated by Wayland as belonging to the arid period between the *Gamblian* and *Makalian* pluvials, but since the cultures of South Africa lagged considerably behind their counterparts in the north this presents no serious difficulty.

At Sawmills in Southern Rhodesia Neville Jones has found an industry of similar type, but it is unfortunately an open surface site and the evidence is therefore not conclusive. At Parma on the Limpopo Schofield has found an industry showing the same intimate association of very advanced Middle Stone Age with *Wilton* tools, and here the occurrence lies on bedrock and is covered by a sterile layer

above which occurs a deposit of the Mapungubwe culture. Nearby, at Mapungubwe itself, a similar occurrence has been noted by van Riet Lowe. Although these sites are still a long way from what we have come to regard as the true home of the Wilton and later Smithfield peoples in the Union, they suggest strongly that the apparent break between the Middle and Later Stone Age cultures may not have been so absolute as our present knowledge has led us to believe. When more excavations of cave sites have been undertaken it would not be surprising to find something approximating closely to the Magosian much nearer home.

The Later Stone Age, too, is by no means without its problems, although as is to be expected, we know more about these cultures than about those which preceded them. Of the cultures of this period the Smithfield A or Koning Culture presents the most difficulty. Its roots seem to lie deep down in the Fauresmith where we find a number of elements—including circular and concavo-convex scrapers—which are absent from most Middle Stone Age assemblages and occur only very rarely in a few Middle Stone Age industries. Are we then to suppose a development, the intermediate stages of which are unknown, from the Fauresmith to the Smithfield A? If so, then such a development must have by-passed the whole of the Middle Stone Age in some region as yet undiscovered. The Smithfield culture was at first thought to be confined to the areas of the highveld of the Orange Free State which provide indurated shale; later a typical early Smithfield industry was found in the Zoutpansberg near Louis Trichardt where a different material was used. More recently Archdeacon Owen has discovered a most interesting site at Nyarindi in Kenya which he described briefly in *Man* (1941), and a type collection from which he kindly sent to the Bureau of Archaeology. Of great significance is the fact that at Nyarindi the site is a sealed rock shelter, and that the Smithfield A elements are there found in undoubted association with Levallois-type flakes. Archdeacon Owen also states that the Nyarindi material antedates the period assigned to the Smithfield A in South Africa. From a comparison with the remainder of his collection from the Kavirondo, Owen concludes that the Kavirondo (Early) Smithfield had a fairly wide distribution in that area and was not confined to the Nyarindi rock shelter site.

This discovery of Owen's opens the way to a totally new conception of the Early Smithfield. Instead of being a locally confined autochthonous culture of the Upper Vaal and Orange River basins, it now appears as something which has its roots deep in antiquity and far afield. The links are missing and the details are still obscure. The complete absence of any trace of the Levallois tradition in the Early Smithfield is the more striking in the light of Owen's dis-

covery. The glimmer of light thrown by the Nyarindi discovery has served to show up the problems of the origin of the Early Smithfield and its relationship to the Fauresmith and the Levallois of the Middle Stone Age; we have not yet arrived at their solution.

The Smithfield B is quite clearly a development from Smithfield A though Goodwin has stressed the Capsian influences present. The Smithfield B culture seems to be confined to the indurated shale areas of the Orange Free State, the Northern Cape and Natal, though the industry in cloudy quartz found in the Oakhurst Shelter at the Wilderness (Goodwin 1938) is an exception and re-opens the question of the distribution of this culture.

As a result of their occurrence in caves and rock shelters much is now known of the so-called "pygmy" cultures. Smithfield C and Wilton, but a new problem has arisen from the finding of small tanged arrowheads in materials similar to those used in the pygmy industries. The problem is not really new, for van Riet Lowe (1929) first described and illustrated three specimens from Modderpoort. Of these he then said :

"It does not seem impossible though admittedly cautious, that these are Smithfield. They are the only known three, and I record the occurrence as one unusually problematical and interesting. The case, however, may be parallel with the De Kiel Oost crescents"

(which he considers do not belong to the industry of the site).

Since those days these tanged arrowheads have been found from Fauresmith and Riverton near Kimberley to the foothills of the Drakensberg and there is reason to believe that they occur in the comparatively unexplored country to the west of Kimberley. They occur consistently with typical assemblages which include large numbers of crescents. It therefore seems that they represent the finest product of an advanced Wilton, and our ideas on distribution of the Wilton must be revised in the light of these finds. Unfortunately all the occurrences so far known are on the surface, and they must remain a problem until they are found by proper excavation in sealed deposits in a stratified rock shelter.

I can here refer only briefly to one of the most interesting branches of our studies—primitive art. Few subjects have excited more interest than this, and no field offers better opportunities for its study. Most of the work that has been done has consisted of making copies and studying occurrences in more or less confined areas or particular sites. Recently the Bureau of Archaeology (1941) has published a list of all the known sites with a map showing their distribution, which should form the basis of an extensive as well as an

intensive survey of our prehistoric art. The sequence of colours or styles established for one area does not necessarily hold good for other areas and much work has yet to be done to work out the true relationship between the art of different areas. A principle which has been generally adopted in the study of sequences and development in prehistoric art is the superposition of colours. Thus Burkitt (1928) and the Abbé Breuil (1930), in addition to local workers, have worked out a number of colour sequences in different sites and areas. There is, however, an important publication by Segal (1935), which has not received the attention it merits and which strikes at the very basis of these studies. Local tradition has it that certain yellow clayey concretions contained in sandstones from the Steynsburg district of the Cape were used as "Bushman paint." Dr. Segal experimented with samples of this material and found that

"In its original form, the material could be used as a yellow opaque pigment of light colour. When heated carefully to varying temperatures and with controlled amounts of air, the combined water was driven off and products of different colours were obtained varying from the original yellow to yellowish reds, brownish reds, dark reds and finally black From the results obtained it was found that the concretions in the sandstone submitted could be used to produce pigments of varying colours of permanent tint and produced paints of good spreading power."

These results were, of course, obtained under laboratory conditions, but Segal suggests that provided the use of fire were known the effects of heat upon material of this nature would have been easily discovered.

The importance of Segal's experiments is at once evident. If an artist started to work with a yellow paint, was interrupted and placed his paint close to a fire, he might return after a time and resume work with the same materials which might now be red instead of yellow. This does not mean that colour superposition is entirely valueless in establishing art sequences, but it demonstrates clearly that such conclusions must be supported by consistency of style, technique and possibly choice of subject.

Because of their occurrence in rock shelters in association with occupational deposits we have been able to establish tentative correlations between rock paintings and stone cultures, but this has not been possible in the case of engravings which invariably occur on open hillsides. We can never associate implements with engravings absolutely, but by the examination of large numbers of sites we may hope to attribute stone cultures to the engravers with some

degree of probability. Goodwin (1936) has described a sequence of techniques in engraving at Vosburg, but here again his results as far as we can be certain apply only to a limited area. The whole subject is a vast and complicated one calling for the attention of someone who can combine the qualifications of the artist, scientist, photographer and expert-copyist. It is unlike most of our other studies in that deterioration by natural forces and vandalism sets a time limit which makes it imperative that such studies be undertaken without delay.

The present state of our science is such that we must perforce still occupy ourselves with matters of detail such as I have outlined. The time has not yet come for large-scale correlation and synthesis of our knowledge, but one of our constant and most important aims should be the tracing of broad cultural streams and influences over the surface of the earth. In recent years archaeologists and geologists have begun to give some attention to the problems of correlation, complicated as they are by problems of time, regions and cultural development. Without exception, all who have come forward with suggestions on these problems have been at special pains to stress the tentative nature of their attempts at correlation and it is clear that the study of these aspects is as yet in its infancy.

It is now very widely accepted that to explain major climatic changes over large portions of the earth it is necessary to turn to an extra-terrestrial phenomenon, namely fluctuations in solar radiation. But cycles of such fluctuations have been worked out only for certain northern latitudes and it is at least doubtful if the results obtained apply to South Africa. Nor do we know how these fluctuations affected the climate in southern latitudes. It is therefore not possible as yet to generalise and apply results obtained in Europe to South African problems.

In South Africa some work has been done on the interpretation of geological deposits in terms of climatic changes and the correlation of associated human artefacts with climatic events. Leakey (1936) and van Riet Lowe (1937) were the first to offer tentative correlations between climatic and cultural events in the Vaal river basin, East Africa and the Sahara-Arabian Belt. Cooke (1941) frankly admitting the inadequacy of the available data, has limited his tentative correlation between climatic and prehistoric cultural events to South Africa only on "the use of lithological, archaeological, faunal and purely geological data." With regard to wider correlations he maintains that the data available are too inadequate to justify such attempts, and points out that van Riet Lowe's suggested correlation for Africa depends on the validity of Solomon and Leakey's work in Kenya on which Solomon has himself (1939) cast some doubt.

The most ambitious correlations have come from T. T. Paterson (1940) who offers a correlation over the whole of the Old World from England to China and from North Germany to South Africa, but his suggestions have been strongly criticised by Cooke, van Riet Lowe and Wells (1940). The same ambitious task has also been undertaken by Huzayyin of the Cairo University in a recent valuable work (1941). It is interesting to note that Paterson takes as his basis

“the recognition of a world-wide system of three easily recognisable major cycles of sedimentation, each beginning with a coarse and ending with a fine facies,”

while Huzayyin suggests, for instance, that the Kamasian pluvial of East Africa corresponds to the whole period occupied in the Alpine region by the Mindel and Riss glaciations as well as the inter-glacial which separates them, and equates Gamblia I with the whole of the Wurm period. This is not the place to discuss the merits of these theories, and little can be gained from discussing their implications at this stage. Suffice it to say that from all that has been written on the subject of world correlation one emerges with the impression that such attempts, stimulating as they may be, are as yet premature.

While our knowledge of the archaeology of the eastern portion of the continent of Africa with the exception of Portuguese East Africa has been growing steadily, information concerning the western portion of the continent has lagged behind. Angola is a blank, and until recently what little we know of the archaeology of the Congo has been confused by misconceptions arising from the so-called Tumbian culture. In recent years the work of Dr. Francis Cabu of Elizabethville has thrown much light on that area, but it is as yet unpublished and available only to those who had an opportunity of meeting Dr. Cabu and examining his specimens when he visited the Union last year. It has now been shown that a long evolution of cultures can be demonstrated in the Congo paralleling the Stellenbosch-Fauresmith evolution in the Union. There, however, the parallelism ends. The Kalinian, or Congo Fauresmith, is followed by a culture for which the name Djokocian has been coined, which includes a Levallois technique and certain Still Bay forms and shows some affinity with the Aterian of North Africa, but differs from both these cultures in important respects. Our knowledge of the Later Stone Age in the Congo is still far from complete, but a few specimens exhibited in Dr. Cabu's collection give promise of something akin to our Smithfield industries.

North West Africa has for some years received a considerable amount of attention from archaeologists, but the work done there has not been available to us. Recently, however, Dr. Frederick Wulsin (1941) of the Peabody Museum has rendered us a valuable service by publishing a synthesis of the results obtained in that region which should be of great assistance to us in the opposite extreme of the continent.

In my opening remarks I referred to the effects of the war on archaeology. In conclusion I must mention two good results of the war. The first was the visit of Dr. Cabu to which I have just referred; the second is the coming to this country of the Abbé Breuil, the acknowledged leader in our subject, who will shortly join the staff of the Bureau of Archaeology. He will be warmly and widely welcomed. We are confident that his work here will contribute in no little measure to the solution of some—we may almost hope most—of our problems.

REFERENCES.

- BROWN, A. RADCLIFFE: On Social Structure, *J. Roy. Anthropol. Inst.* Vol. LXX, Pt. 1. (1940).
- BURKITT, M. C.: *Man*, 139 (1936).
- CLARK, GRAHAM: Archaeology and Society, Methuen, London (1939).
- COOKE, H. B. S. AND CLARK, J. D.: New Fossil Animal Remains from the Victoria Falls, N. Rhodesia, and a Preliminary Note of the Geology and Archaeology of the Deposit. *Trans. Roy. Soc. S. Afr.* Vol. XXVII, Pt. III (1939).
- COOKE, H. B. S.: A Preliminary Survey of the Quarternary Period in Southern Africa. *Bur. of Arch., Arch. Ser.* No. IV, Govt. Printer, Union of S. Afr. (1941).
- COOKE, H. B. S., LOWE, C. VAN RIET AND WELLS, L. H.: Geology and Early Man, *Nature*, 147: 45-49 (1941).
- CRAMB, J. GORDON: Early Stone Age in Natal. *This Journal*, XXXII: 488-493 (1935).
- CRAMB, J. GORDON: Further Notes on the Tugela Industry. *This Journal*. XXXIII: 950-959 (1937).
- GOODWIN, A. J. H. AND LOWE, C. VAN RIET: The Stone Age Cultures of South Africa. *Ann. S. Afr. Mus.* XXVII: 109-118 (1929).
- GOODWIN, A. J. H.: In Haughton, S.H.: The Geology of Cape Town and Adjoining Country, Explan. of Sheet 247. Geological Survey, Union of S. Afr. (1938).
- GOODWIN, A. J. H. AND MALAN, B. D.: Archaeology of the Cape St. Blaize Cave and Raised Beach, Mossel Bay. *Ann. S. Afr. Mus.* XXIV, Pt. 3, 131-140 (1935).
- GOODWIN, A. J. H.: A Commentary on the History and Present Position of South African Prehistory, *Bantu Studies*, IX, No. 4, 334 (1935).
- GOODWIN, A. J. H.: Vosburg: Its Petroglyphs. *Ann. S. Afr. Mus.* XXIV, Pt. 4 (1936).
- GOODWIN, A. J. H.: The Archaeology of the Oakhurst Shelter, George. *Trans. Roy. Soc. S. Afr.* XXV. Pt. III (1938).

- HUZAYYIN, S. A.: The Place of Egypt in Prehistory, *Memoires de l'Inst. d'Egypte*, Vol. 43, Cairo (1941).
- LEAKEY, L. S. B.: Stone Age Africa, Oxford (1936).
- LOWE, C. VAN RIET: *Man*, 266 (1936).
- LOWE, C. VAN RIET (WITH SÖHNGE, P. G. AND VISSER, D. J. L.): The Geology and Archaeology of the Vaal River Basin, Geological Memoir No. 35, U. of S. Afr. Geological Survey (1937).
- LOWE, C. VAN RIET: See Goodwin and van Riet Lowe, 1929.
- LOWE, C. VAN RIET: A Projected Regional Survey of the Prehistory of South Africa, *Bur. of Arch. Ser. No. II*, Govt. Printer, Union of S. Afr. (1938).
- LOWE, C. VAN RIET: Prehistoric Art in South Africa. *Exp. of Map.*, *Bur. of Arch. Ser. No. V*, Govt. Printer, Union of S. Afr. (1941).
- MALAN, F.: The Stellenbosch Industry in the Wagenmakers Valley, *Trans. Roy. Soc. S. Afr.* XXVII, Pt. III (1939).
- McFARLANE, D. R.: Evidence in Support of a Pre-Chellean Culture from the East London Clays. *This Journal*, XXXII, 537-550 (1935).
- O'BRIEN, T. P.: *Man*, 196 (1936).
- OWEN, W. E.: *Man*, 76 (1941).
- PAATERTSON, T. T.: Geology and Early Man, *Nature*, 146, 12-15 and 49-52 (1940).
- SHAND, S. J.: The Terraces of the Eerste River at Stellenbosch, *Trans. Geol. Soc. S. Afr.* XVI, 147-155 (1913).
- SMUTS, J. C., JNR.: Past Climates and Pre-Stellenbosch Stone Implements of Rietvlei (Pretoria) and Benoni. *Trans. Roy. Soc. S. Afr.*, XXV, Pt. IV (1938).
- VAN HORPEN, E. C. N.: Enige Gesigspunte in die Suid-Afrikaanse Argeologie, *This Journal*, XXXV, 92-125 (1938).
- WAYLAND, E. J.: Some Account of a Pebble Industry in the Transvaal, *Trans. Roy. Soc. S. Afr.* XVII, 330-340 (1929).
- WAYLAND, E. J. AND BURKITT, M. C.: The Magosian Culture of Uganda, *J. Roy. Anthropol. Inst.* LXII, 369-389 (1932).
- WEILIN, F.: The Prehistoric Archaeology of Northwest Africa, *Papers of the Peabody Mus. of Arch. and Eth.* XIX. No. 1 (1941).

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FAR EASTERN CONTACTS WITH SOUTHERN AFRICA

BY

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Presidential Address to Section F, read 30th June, 1942.

Eastern influences upon Africa south of the equator have been voluminously discussed, and those of Arabia and Persia are reasonably clear, though how far they go back in time is a question which still remains to be answered. That of India is established though perhaps less defined. But the subject of ancient communication between the Far East and Africa is obscure, though details bearing upon it seem discernible in the mosaic of customs, crafts and legend which presents itself to the inquirer.

People interested in weapons and handicrafts and in old-time trade have found in the East Indies and elsewhere threads which, when followed, have led to Madagascar, Zanzibar and the adjacent mainland. A reciprocal interest has of late been created here and the subject, hitherto only touched incidentally in publications relating to East Africa, is likely to receive more attention in the Union and Rhodesia.

This last fact, and not any desire to deal topically with a part of the world which has been thrown luridly into prominence as a result of the war, is my reason for attempting a rough sketch of the slender but fascinating information available. Indeed it would not have been possible to do even that had the intention not been formed, and most of the material gathered, before the war.

We are all aware of the close relations which were established in comparatively recent times between the Cape and Java, when Batavia was the point from which the Cape was governed on behalf of the Dutch East India Company. The Malay immigration which took place at that time is a commonplace of our history; one of the things which fall to be examined is a theory that five hundred years or more before these people were introduced, commercial relations had been established between the East Indies and our East coast.

Another suggestion which rests to some extent on historical fact is that Chinese traders and sailors may have exerted an influence upon some of the tribes which, coming down from sources in the north or centre of the Continent,

marched and mingled in the strange migrations which resulted in the presence of the Bantu, Hottentot and Bush tribes in the areas they occupied when the Europeans arrived.

This mention of Chinese is a warning to me to tread warily. In a paper submitted to this Association in 1926 I had occasion to mention Chinese ships having called at Mogadishu on the Somaliland Coast in 1430 and at other ports in East Africa on earlier occasions. The late Professor E. H. L. Schwarz, who was intensely interested in ethnic problems, made this the basis of a popular article in which he sketched the consequences of such visits to a pre-Bantu Southern Africa, especially, of intermarriage between the Chinese and whatever inhabitants there were at that time. One of the suggestions in that little fantasy was that the Hottentots, whose origin is so obscure, might owe their existence to such circumstances. This idea he elaborated more seriously in the Nation, a review which was published in the Union at that time. Finally, he wrote an exhaustive paper, which appeared, several years after his death, in the Journal of the Asiatic Society of Bengal (1938).

Since then I have had to meet innumerable questions as to whether a famous scientist had not proved that the Hottentots were descended from Chinese sailors who visited the coast at some remote period. I do not believe, in fact, that this idea will ever be overtaken; and with the consequences of my innocent action thus impressed upon me, I have a certain diffidence, even after sixteen years, in speaking of Far Eastern visitors.

As a preface to the subject generally I ask you to recall that the Arab geographers to whom we owe our knowledge of the Indian Ocean prior to the Portuguese discoveries called the black inhabitants of East Africa the Zenj and their country the Land of Zenj. Below them, somewhere south of the Zambezi, were what was apparently a distinct people, the Wakwak. They were savages who talked some uncouth tongue, and the fact that the Arabs and Persians really knew little about them is indicated by a complete absence of detail.

El Masudi, perhaps the best known of such compilers, wrote of "The county of Sofala and the Wakwak." That is the only instance I know in which Sofala or any other known locality is specifically associated with this Wakwak region; but the implication in most cases is that it was over against Madagascar.

South African commentators have usually set down the Wakwak as the Bushmen (Batwa), the Hottentots (Khoi-Khoi) or some native tribe. There are actually tribes on the coast named Wakwati and Makwakwa, but the second at all events—which is one of the Thonga or "Shangaan" group living between the Limpopo and Inhambane—probably originated too late to account for a name which was current

in the earlier Middle Ages. In any case, the name was not confined to Africa but appears six thousand miles away in the East Indies. Edresi, who wrote a century and a half after Masudi, said that "the people on the island of Zabaj come to the country of Zenji in large and small ships and use it as a centre for trading in their merchandise, as they understand one another's language."

Zabaj was the name of a considerable kingdom, also known as the Empire of the Mahraj, which included Java. Sumatra, some of the other islands, and probably part of the Malay Peninsula. That it was also known as Wakwak is made clear in the Hudad-al-Alam, the comprehensive Persian treatise on the Regions of the World, which places Wakwak on the confines of the Green Sea (by which is meant the Bay of Bengal and its approaches) and describes it as adjacent to China, of which it had by that time become a dependency. Only shreds of information remain to testify to the wealth and prestige it seems to have enjoyed up to about the seventh century, and the only description that has survived is the one recorded by Abu Said as having been received from an old man who in his youth visited China and some of the countries to the south of it. "The province of Zabedge" he said, "is opposite to China, distant a month's sail or less. The king of the country is styled Mehrage, and his kingdom is said to be 900 leagues in circumference, besides over many islands."

The wealth of the country was such that the King, every day, caused an ingot of gold to be cast into the lake in front of his palace, the collection so formed being taken up when he died, to be distributed to the poor. This mention of gold has served to strengthen an assumption that people from Zabaj worked the old gold mines in Mashonaland, or at least traded gold from the natives on the Sofala coast before the Arabs arrived there. That is not impossible, but it must be remembered that gold was freely produced in Sumatra, so that it is not necessary to go to Africa to account for the Zabaj King's possession of it.

What is more interesting, perhaps, is a decided similarity in mining methods in Mashonaland and in the Malay area—the narrowness of the cuttings in many of the "ancient" mines in Rhodesia has often been commented upon, leading to a suggestion that the diminutive Bush people were employed as slaves on the mines. Anyone who knows the Bushman temperament will reject the supposition that these wild little people could have been set to work, even as slaves, and kept at it to the extent which the huge workings scattered over Rhodesia imply; and there is, furthermore, the fact that gold extraction went on in the area in question into historical times, the work being done by natives working in

gangs of men, women and children. The workings and the rough tools found in them have been compared to similar things in India. That may be correct, but they correspond to a surprising degree with Malayan and Sumatran mines as described by engineers writing with no thought or knowledge of the Rhodesia problem.

But apart from the fact that Zabaj and the hinterland of Sofala both had gold, there seems to have been some intimate connection between the two countries, so different in their states of civilisation and situation in the world, which were known as Wakwak. At a long shot the African one may have been so called because it was a sort of colony of the Asiatic state, in the same way as places like New Zealand and South Georgia and Brazil (which is so called because it produces dye woods similar to the Brazil tree of the East Indies) acquired their names.

With these facts and speculations in mind, it was startling to have had, at the 1939 meeting of the Association, a calmly given assertion that a native tribe in Rhodesia claims descent from people who came over the sea, from a country of high volcanic mountains (such as are found in Java and Sumatra) by way of Madugascar. The author of the paper, Mr. J. Blake Thompson, is a hospital official in Salisbury, and it was while investigating the physical characteristics of some of the natives of the Middle Zambezi valley that he came upon this information. Its gist is that the royal clan of the widely scattered Nyungwe tribe—this royal clan apparently being called the Aulaya—left an ancestral home in the Empire of Milanje, three months by ship from Madagascasr, under a great leader called Munyu, a name which Mr. Blake Thompson considers was really “Ming Yung.” When Mr. Thompson, who was evidently acquainted with the tradition of the Zabaj or Mahraj kingdom, told his informant about that country, the answer was that the Arabs pronounced Milanje as “Mahraj.” The man, who claims descent from Ming Yung himself, said that the Aulaya landed on the Sabi river (near Sofala) and went on to Tete—the Bantu had not yet arrived, nor were there Arabs there; but there were Indians, with whom the Aulaya had been neighbours before they came to Africa. In the country round Tete there were no fixed inhabitants, but only some people who appeared from time to time—“These were fair-skinned; they spoke with a click like monkeys, but were taller than the pygmies and they herded cattle.”

Here, you may well say, is the other end of the story of the lost Empire of the Mahraj and clear confirmation that the country of the Wakwak in Africa was a colony, from which the Mahraj drew gold, ivory, leopard skins, and the other articles which are referred to as having been its products. But the people of this colony would rather plainly

have been the Hottentots, seeing that the Bushmen did not have cattle. Personally, I find two difficulties. One is that the history is so remarkable, so unparalleled in African tradition, that its discovery is almost too good to be true. The other is that its preservation over the time that has elapsed is well nigh incredible when we consider that no clear narrative of past events has been preserved elsewhere in the Bantu area for more than three centuries.

If this feeling is shared by others, that may account for the indifference with which Mr. Thompson's tradition has been treated. But if there is no catch in it—no misunderstandings such as are easy in the process of taking information from natives—it is the most important that has been unearthed in the Bantu area during the present century. Had it not been for the war it might well have been followed up and thoroughly tested before now, and when the opportunity for doing this recurs, it should be marked for special attention.

I have dealt with this Zabaj country at some length because, whether the Aulaya tradition is accepted or not, Zabaj may prove a key to the problem of ancient trade across the Indian Ocean. Whether its people or the Malays who colonised Madagascar were first in the field it is difficult to decide. It is clear that the Malay connection with Madagascar commenced at a very early stage. For one thing there are no Indian words in the Hova language of Madagascar, which means that the Malays went to the island before Indian settlers appeared in the East Indies and introduced Indian speech, customs and literature there.

This Indian infiltration started at a very early date. Fah Hain, the Chinese traveller whose account of those regions is the earliest personal one, said in 412 A.D. that there were Hindu colonies in Java. Two centuries later the drift in that direction was accentuated, and by the year 800 the tide of migration was at its full. A romantic history of one of the events which gave impetus to it is recorded by Sir Stafford Raffles in His History of Java, and has been confirmed from Indian sources. It was foretold to a King of Gujarat that his country would fall into decay, so he resolved to send his son to Java. The son embarked with about 5,000 followers in six large and a hundred small vessels, and subsequently, when the settlement had proved successful, a further 2,000 men were sent. "From this period Java was known and celebrated as a kingdom. An extensive commerce was carried on with Gujarat and other countries and Matarem (the chief town of the settlement) was filled with adventurers from all parts."

This activity was not reflected in the trade with Africa. On the contrary, that appears to have declined rapidly, passing into the hands of people from India and of the Arabs

and Persians who were, or now became, ascendant on the coast. But even to them the coast below Sofala remained to a great extent unknown and mysterious, protected by legends of magnetic mountains which drew the nails out of ships and of seas from which the voyager never returned. But it will be seen that we do have from Arab, Persian and to a small extent from Chinese sources, some written and reasonably authenticated records of the contacts between Indonesia and Southern Africa, which are substantially more definite than indirect evidence such as the presence of the Javanese bar zither and the double outrigger canoe in East Africa and purely fanciful parallels between Indo-Javanese temples and Rhodesian buildings of the Zimbabwe type.

The medieval authors must, nevertheless, be quoted with great caution. Some of them utterly confused Khmer, a country in what we now call Indo-China, with Komr, which was the Arab name for Madagascar. Others, including Edresi in the map of the world which he drew up for King Robert of Sicily, showed the Malay Peninsula and Madagascar, the Island of the Malays, as one. In order to reconcile all this with the position of India in relation to Africa, they made the coast of south-east Asia approach that of Southern Africa in a great bend to the westward.

We have now worked our passage back to China, and it is interesting to find that a new examination of what is available on the subject of African voyages from that country has been published. In the last two issues of *Nada* (the Native Affairs Department annual of Southern Rhodesia) Mrs. C. E. Fripp has discussed Chinese and other pronouncements on this point, including the suggestions made by Professor Schwarz. Her results do not support either the idea that those voyages commenced at a very ancient date or that they could have had any marked effects on either the people or the industries of our coast. Quoting Professor Duyvendak, of Leyden, a leading authority on Chinese history, Mrs. Fripp shows that it is improbable that the Chinese reached the African area before about 1416, and that they merely traded with the ports at which the Arabs and Persians had long been established. Actually there was never very much to support the idea of an ancient Chinese intrusion into Africa. The Chinese sea trade was developed westward only after China had subjugated part of the Malay area—we have seen that by the tenth century Zahaj had fallen into its sphere of power—and had acquired information about the Indian Ocean from the Malays who seem to have been its pioneers.

There may, of course, be something further to be had from China. There is, indeed, a great deal still to be done generally in the way of inquiry into the history of Asia's contributions to ancient and medieval Africa.

REFERENCES.

- BEALE, REV. S.: Travels of Fah-hain and Sung-yun, Buddhist Pilgrims from China to India.
- BELFIELD, H. C.: Handbook of the Federated Malay States (for ancient mining methods in this area).
- EDRESI: Map of the World (1154 A.D.) in *Monumenta Cartographica* (Prince Youssuf Kamal), Tome 3, Fascicule 4.
- EL MASUDI: French translation and annotation ("Les Prairies d'Or") by Barbier de Meynard and Pavet de Courteille.
- FRIPP, C. E.: Chinese Medieval Trade with Africa: *Nada*, 17, 18.
- HUDAD-AL 'ALAM ("Regions of the World"); translation and notes by V. Minorsky.
- JUNOD, H. A.: (for names of Thonga clans): The Life of a South African Tribe, Vol. 1.
- PAVER, F. R.: Far Eastern Contacts with Southern Africa. This Journal, XXXIX, 88 (1942).
- RENAUDOT, E.: Travels of Two Mahomedans in India and China in the Ninth Century: in Ker's Voyages and Travels, Vol. 1.
- THOMPSON, J. B.: The Oriental Ancestry of the Aulaya-'Nyungwe. This Journal, XXXVI, 464-467 (1939).

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NOTE ON HEAT FLOW: THE FLOW OF HEAT TOWARDS
THE RECEDED FACE OF A SEMI-INFINITE SOLID.

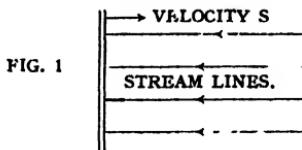
By

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Read 29th June, 1942.

1. *Statement of the Problem.* We are given a semi-infinite solid originally at a constant temperature u_0 °C, and from zero time onwards ($t > 0$) the plane face of the solid is maintained at some lower constant temperature u_1 °C. Heat then flows towards this face with the stream lines perpendicular to the face as indicated in Fig. 1. But the solid at the face is meanwhile dissolved away, so that the face itself recedes with a constant velocity of s cm./sec.



The problem is to find the temperature u °C at any distance x cm. behind the moving face after a time t secs., and also to find the rate at which heat is being removed from the face after a time t secs.

2. *Solution of the Problem.* The solution of this problem was stated without proof (1). The required temperature u is given by

$$\frac{u - u_1}{u_0 - u_1} = \frac{1}{2} + \frac{1}{2} \operatorname{Erf} \frac{x+st}{2\sqrt{at}} - \frac{1}{2} \left\{ 1 - \operatorname{Erf} \frac{x-st}{2\sqrt{at}} \right\} e^{-sx/a} \quad \dots\dots(1)$$

where $\operatorname{Erf} x$ is the error function of x defined by

$$\operatorname{Erf} x = \frac{2}{\sqrt{\pi}} \int_0^x e^{-z^2} dz,$$

and where a =diffusivity of the solid in c.g.s. units,

$$= \frac{\text{thermal conductivity}}{\text{specific heat} \times \text{density}}.$$

a is assumed to be constant. After a long time (t large) equation (1) approximates to

$$\frac{u - u_1}{u_0 - u_1} = 1 - e^{-sx/a} \quad \dots\dots(1A)$$

The rate at which heat leaves the face in calories per sq. cm. per sec. at any time t is equal to

$$k(u_0 - u_1) \left\{ \frac{s}{2a} + \frac{s}{2a} \operatorname{Erf} \frac{s\sqrt{t}}{2\sqrt{a}} + \frac{1}{\sqrt{\pi a t}} e^{-s^2 t / 4a} \right\} \quad \dots \dots \dots \quad (2)$$

where k is the thermal conductivity of the solid in c.g.s. units, assumed to be constant. After a long time expression (2) approximates to

$$k(u_0 - u_1)s/a. \quad \dots \dots \dots \quad (2A)$$

3. *How the Solution is Derived.* This problem is one-dimensional, similar to problems concerning the flow of heat along a rod. The required temperature has therefore to be a solution (3) of the differential equation

$$\frac{\delta u}{\delta t} = a \frac{\delta^2 u}{\delta y^2}, \quad \dots \dots \dots \quad (3)$$

where the y -axis is stationary, and is perpendicular to the face, and has its origin coinciding with the face at time $t=0$. In addition the solution has to satisfy the initial condition

$$u=u_0 \text{ at } t=0, \quad \dots \dots \dots \quad (4)$$

and the boundary condition

$$u=u_1 \text{ at } y=st. \quad \dots \dots \dots \quad (5)$$

It can be shown (4) that a solution of equation (3) is

$$\frac{u-u_1}{u_0-u_1} = \frac{1}{2\sqrt{\pi a t}} \int_{-\infty}^{+\infty} f(z) e^{-(y-z)^2/4at} dz, \quad \dots \dots \dots \quad (6)$$

where the function f is arbitrary. f must be chosen so as to make u satisfy the conditions (4) and (5). Bearing in mind that (6) is known to be the solution of an infinite rod problem in which the initial value of $(u-u_1)/(u_0-u_1)$ is $f(y)$, we satisfy condition (4) by choosing $f(z)=1$ when $z>0$. Then (6) can be written in the form

$$\frac{u-u_1}{u_0-u_1} =$$

$$\frac{1}{2\sqrt{\pi a t}} \left\{ \int_0^\infty e^{-(y-z)^2/4at} dz + \int_0^\infty f(-z) e^{-(y+z)^2/4at} dz \right\} \quad \dots \dots \dots \quad (7)$$

and we can now satisfy condition (5) by putting

$$e^{-(y-z)^2/4at} + f(-z) e^{-(y+z)^2/4at} = 0$$

when $y=st$, which gives $f(z) = -e^{-st/a}$ when $z<0$. $f(z)$ is now defined everywhere except at the point $z=0$ where it is discontinuous. Its substitution in (7) leads after integration to

$$\frac{u-u_1}{u_0-u_1} = \frac{1}{2} + \frac{1}{2} \operatorname{Erf} \frac{y}{2\sqrt{at}} - \frac{1}{2} \left\{ 1 - \operatorname{Erf} \frac{y-2st}{2\sqrt{at}} \right\} e^{-(y-st)s/a} \quad \dots\dots(8)$$

It can be verified by direct substitution that this value of u is a solution of (3) and does satisfy conditions (4) and (5). Since the solution of the problem is known to be unique (3), this is *the* solution of the problem. If we now change from the stationary y -axis to an x -axis moving with velocity s so as to keep its origin in the moving face, then $y=x+st$ so that equation (8) transforms into equation (1).

The rate at which heat flows across the face $y=st$ at any time t in calories per sq. cm. per sec. is equal to the value of $-k(\delta u / \delta y)$ at $y=st$. Substituting for u from equation (8) and transforming to the moving x -axis, we have the rate at which heat flows through the solid to meet the face $x=0$ at time t in calories per sq. cm. per sec. given by equation (2).

4. Practical Application. This problem is an idealisation of the conditions near a stope face in a mine. Due to daily blasting the stope face recedes by a series of sudden jumps. In our problem these jumps are smoothed out into a slow continuous movement.

Curves computed for a particular case using an average diffusivity and conductivity for the rock on the Witwatersrand and a face receding by 6 inches per day have been given (4). In this case it was seen that our equations (1) and (2) reach their final forms (1A) and (2A) after about two weeks.

It is interesting from the physical point of view to contrast the conditions due to the receding face with the conditions when the face remains fixed. At any given distance behind a fixed face the temperature falls eventually to the temperature $u_1^\circ\text{C}$ of the face. But when the face recedes, the temperature at a given distance behind it falls to a definite value between u_0 and $u_1^\circ\text{C}$ and stays there. Again when the face is fixed the rate at which heat flows out through it falls eventually to zero. But when the face recedes, the rate at which heat flows out through it falls to a finite value, and stays there. For the receding face is for ever moving towards the hotter rock. Although the rate at which heat flows out at first depends on the conductivity of the rock, the final equilibrium value is independent of the conductivity. For the ratio k/a in expression (2A) is independent of k . Physically the equilibrium stage is reached when the quantity of heat coming out per second is equal to the heat emitted by a slab of the rock with the same surface area and thickness s cm. on cooling from u_0 to $u_1^\circ\text{C}$. These equilibrium conditions were first pointed out on physical grounds by Professor Paine (5).

REFERENCES.

1. WILES, G. G.: *Jnl. Chem. Met. Mng. Soc. of S.A.*, Feb. 1940, 281.
2. CARSLAW: Conduction of Heat, Chap. 2.
3. CARSLAW: *Ibidem*, Chapter 1.
4. WILES, G. G.: *Jnl. Chem. Met. Mng. Soc. of S.A.*, Feb. 1940, 284.
5. PAINE, H. H.: *Ibidem*, Nov. 1939, 188

SOUTH AFRICAN JOURNAL OF SCIENCE, Vol XXXIX, pp 98-101.
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THE USE OF A STRONTIUM SUB-FLUORIDE BAND IN THE SPECTROCHEMICAL ANALYSIS OF FLUORINE

BY

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Read 29th June, 1942.

The use of the sub-fluoride band of calcium with head at λ 5291 Å is a well known spectrochemical test for fluorine. The test is carried out by arcing the material in the presence of calcium, which if not already present in the material must be added in the form of one of its salts, as for example, calcium carbonate or sulphate.

As strontium and barium were found to behave in an identical manner it was decided to carry out tests to ascertain whether or not they could replace calcium as an alternative test for fluorine. This was suggested by the writer (1942). Beryllium and magnesium also furnish sub-fluoride bands, but as these bands are very weak and diffused they could not be utilised to advantage.

QUALITATIVE ANALYSIS.

Hoag, Papish and Snee (1930) determined the sensitivity of the calcium sub-fluoride band with head at λ 5291 Å as 0.009 mgs. of fluorine. This sensitivity was redetermined with the apparatus available, in order that the sensitivities of the calcium, strontium and barium sub-fluoride bands could be compared under similar conditions.

The apparatus available was a Hilger E 492 automatic quartz spectrograph. A current of $6\frac{1}{2}$ amps was maintained across an arc gap of 5 mm., the time of exposure being 30 seconds in each case. The material under observation was placed on a graphite anode of 10 mm. diameter as previous experience had shown that the use of the cathode offered no advantages. The cathode had a diameter of 6 mm. and was sharpened to a point. The plates used were Ilford Iso-Zenith with an H. and D. speed of 700 and were developed for three minutes in Ilford I.D.2 developer at 22° C.

Standard fluorine solutions were prepared by dissolving 0.442 grams of pure sodium fluoride in 250 ml. of water. This stock solution was then diluted to produce solutions containing 0.04, 0.02, 0.01, 0.005, 0.0025 and 0.00125 mgs. respectively of fluorine per 0.1 ml. of solution.

Three separate solutions containing calcium, strontium and barium respectively were prepared by dissolving the carbonates in acetic acid and adjusting the solutions so that each solution contained 5 mgs. of alkaline earth per 0.1 ml. of solution. For each test 0.1 ml. of one of these latter solutions was pipetted out on to the cupped electrode together with 0.1 ml. of one of the fluorine standards. The electrodes were then dried and arced.

The calcium sub-fluoride band with head at λ 5291 Å was definitely detectable at 0.0025 mgs. of fluorine while below this amount it could not be observed with any degree of certainty.

This result is in close agreement with a previous estimation by the writer (1942) on phosphate rock in which case the sensitivity was determined also as 0.0025 mgs. of fluorine. These results are not in agreement with those obtained by Hoag, Papish and Snee (1930) who reported the sensitivity in complex material at about 0.025 mgs. The increased sensitivity in complex material reported by the writer was found to be chiefly due to the addition of finely powdered charcoal in a 1:1 proportion to the material under observation. Dr. B. Wasserstein (private communication) of the Union Geological Survey has corroborated this result and found that in the case of rocks also, the sensitivity was approximately 0.0025 mgs.

S. Datta (1921) had maintained that the band with head at λ 6064 Å was the most persistent and this was also reported by the writer (1942). Subsequently, however, due to the publication of Gaydon and Pearse's book, "The Identification of Molecular Spectra" these observations were found to be erroneous, the apparent sensitivity being due to the overlapping of a band of calcium oxide. Gaydon and Pearse's work is the first of its kind, it has been found useful and should prove a valuable aid to spectroscopists.

The most persistent strontium sub-fluoride band was the one with head at λ 5772 Å. It was found to be as sensitive as the calcium sub-fluoride band and could be detected when 0.0025 mgs. of fluorine were present in the arc. This band is very clear and sharp and as a result is probably slightly superior to the calcium sub-fluoride band. (Plate I.)

In the case of barium, the sub-fluoride band with head at λ 4992 Å was found to be the most sensitive. It was also very persistent but due to a considerable masking effect in the background, no definite sensitivity could be ascertained. Due to this background effect, this barium sub-fluoride band would be inferior to those of calcium and strontium.

QUANTITATIVE ANALYSIS.

The calcium sub-fluoride band with head at λ 5291 Å was first utilised by Petrey (1934) and has been used extensively by the writer (1942), and by others.

Using standard fluorine solutions of a wider range than those utilised for the qualitative tests, a series of spectra of the sub-fluoride bands of calcium and strontium were obtained.

Plate (2) shows the variation in intensity of the calcium sub-fluoride band with change of fluorine content, while plate (3) shows the intensity variation for the strontium sub-fluoride band. From these two plates it can be seen that the strontium sub-fluoride band could be used equally well in quantitative analysis.

ACKNOWLEDGMENT.

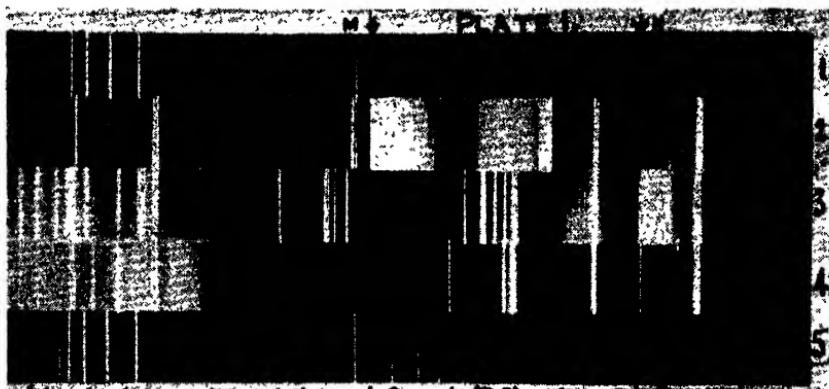
Thanks are due to Professor Taverner for permission to publish this paper.

SUMMARY.

1. The sensitivity of the calcium sub-fluoride band with head at λ 5291 Å has been re-determined.
2. The sensitivity of a strontium sub-fluoride band with head at λ 5772 Å has been determined and found to be an equally sensitive test for fluorine and suitable for quantitative determinations; it can thus serve as an alternative test especially where atomic lines might interfere with the calcium sub-fluoride band.
3. In the case of barium, the sub-fluoride band with head at λ 4992 Å, although very sensitive, was found to be inferior to those of calcium and strontium.

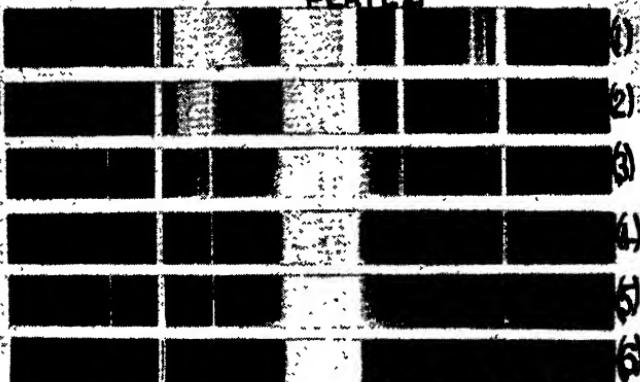
REFERENCES.

- AHRENS, L. H.: *Journal of the South African Chemical Institute*, **25**, 18 (1942).
- DATTA, S.: *Proc. Roy. Soc., Ser. A.* **99**, 448 (1921).
- PAPISH, J., HOAG, L. E., AND SNEE, W. E.: *Ind. Eng. Chem., Anal. Ed.* **2**, 263 (1930).
- PETREY, A. W.: *Ind. Eng. Chem., Anal. Ed.* **6**, 343 (1934).



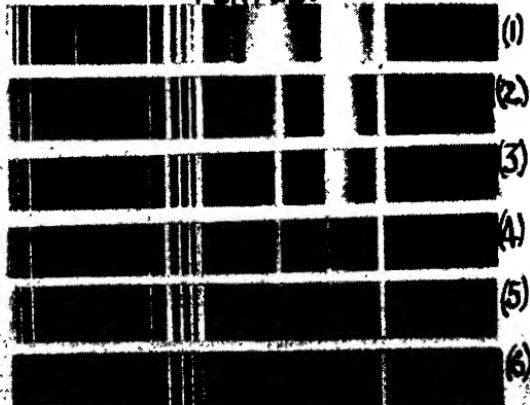
1. Calcium Fluoride; 2. Calcium Sub-fluoride; 3. Strontium Sub-fluoride; 4. Barium Sub-fluoride; 5. Potassium Fluoride; 6. Sodium Fluoride.

PLATE 2.



(1) 30% Fluorine; (2) 10% F; (3) 0.5% F; (4) 0.02% F; (5) 0.005% F.
(6) 0.02% Fluorine

PLATE 3.



(1) 30% Fluorine; (2) 10% F; (3) 0.5% F; (4) 0.02% F;
(5) 0.005% F; (6) 0.02% Fluorine

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THE CONSTITUTION OF THE LANGEBAAN PHOSPHATE ROCK

BY

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Read 29th June, 1942.

A bulk sample, representative of the phosphatic material from Langebaan Road, C.P., was collected by Dr. F. C. Truter of the Geological Survey and sent to the Minerals Research Laboratory for examination and treatment. Much of the sample consisted of phosphatised sand, but lumps of phosphatised silcrete and clay as well as nodules of "phosphorite" were present. In the field phosphatised sands and silcrete underlie layers containing nodules.

The field characteristics of the deposit have already been described. (Haughton, 1932). Analyses given by Haughton indicate only a small percentage of iron and aluminium phosphates; the greater part of the phosphorus being in some combination with calcium. Analyses of the bulk sample and graded fractions prepared in the Minerals Research Laboratory substantiate this.

Very little information as to the exact nature of the phosphate mineral is obtained from thin sections of the various phosphatised rocks. Apparently it is in all cases isotropic and shows no features by which it can be accurately identified. Apart from routine examinations, the more interesting rock types were more intensively studied and are described separately.

A sample of green phosphatised clay was found to be composed of quartz grains, pale lemon, translucent phosphate and a small percentage of an almost isotropic clay mineral. This clay mineral has a mean refractive index of 1·47 and absorbs dyes strongly. The slime portion of the clayey material was treated with weak HCl to dissolve the phosphate and an X-ray picture of the insoluble portion indicated that the clay mineral belongs to the montmorillonite group.

The phosphate nodules which are semi-resinous in appearance are coated with greenish clay. The interior is brown with a thin crust paler brown or white in colour. Several of these nodules were coarsely crushed and the brown and white fragments separated for analysis. (Table I, b and c).

The abrupt colour change in sections cut across white and brown portions is not accompanied by any variations in the isotropic nature of the material. Thin vague layers of limonite are revealed in the brown portion and sparsely distributed quartz grains occur throughout the entire nodules. The mean refractive index of the white phosphate is $1.611 \pm .002$ and that of the brown is slightly higher, varying from 1.615 to $1.62 \pm .003$.

TABLE I.

	<i>a.</i>	<i>b.</i>	<i>c</i>
SiO_3	35.8	14.3	3.9
TiO_3	0.3	0.1	0.1
Al_2O_3	9.1	5.8	3.1
Fe_2O_3	4.6	2.1	7.7
MgO	tr	tr	nil
CaO	23.4	41.9	44.7
P_2O_5	14.3	27.6	27.9
$\text{H}_2\text{O} +$	4.21	1.05	4.51
$\text{H}_2\text{O} -$	5.79	2.95	1.79
CO_2	2.1	3.0	6.4
F	1.4	2.5	2.5
Less O=F	101.0 0.59	101.3 1.05	102.6 1.05
	100.41	100.25	101.55

a. Green phosphatised clay.

b. White portion of nodules.

c. Brown portion of nodules.

Analyst: L. W. Vermeulen.

The ratio of P_2O_5 to F in the nodules and the clay is the same as in fluor-apatite. There is, however, an excess of CaO over that required for fluor-apatite, and the greater part of the excess is in combination as carbonate, while a small amount of calcium sulphate is also present. A composite sample of nodules was found to contain 0.60% SO_4 .

X-ray powder photographs were taken of the two portions of the nodules, and also for comparison, of fluor-apatite, hydroxy-apatite (dental enamel), and artificially prepared tricalcium phosphate. A circular camera of diameter 5.74 cms. and Cu K α radiation were used. The X-ray photographs of these apatite minerals are almost identical having only slight variations in lattice dimensions.

According to Thewlis et al. (1939), the most striking differences in the X-ray photographs of apatites are in the relative positions and intensities of the (121, 211), (112) and (300) reflections. The (121) and (112) lines are clearly

separated in hydroxy-apatite but almost merge in fluorapatite. This resolution was not obtained in my photographs owing to the small scale on which they were taken. There is consequently overlapping of the (121) and (112) lines and they appear as one rather broad line in hydroxy-apatite, which is, however, distinct from the narrower line in fluorapatite. The photographs of both portions of the nodules differ from both chlo₁- and hydroxy-apatite as well as from chemically prepared tricalcium phosphate. They are, however, similar to that of fluor-apatite.

Thus X-ray evidence supports the conclusion drawn from the chemical analyses, that the phosphate is present as a fluor-apatite. A combined chemical, mineralogical and X-ray study of secondary phosphate deposits from various parts of the world has shown that in the majority of these, the phosphate mineral is a sub-microcrystalline fluor-apatite. (Hendricks, S.B., et al, 1931).

In the analysis of the white part of the nodules a considerable percentage of silica is reported, whereas the corresponding thin sections show approximately 3% of quartz grains. The brown phosphate has less silica but more iron and aluminium which are present partly as clay and hydrated oxides. The residues obtained from the two samples after dil. HCl treatment were well washed and divided into sand and slime fractions. In both cases the sand fraction was less than 10% of the residue and the remainder, composed of slime gave an X-ray pattern, which, although weak, resembled that of montmorillonite. The slime contained 76% SiO₂ and 11.4% of combined water.

Microscopical examination showed that the bulk of the slime consisted of particles of a white translucent to transparent isotropic mineral which had a refractive index of 1.45 and is probably a type of colloidal silica or opal. Even after a long exposure this material failed to produce a distinct X-ray diffraction pattern. Staining tests clearly differentiated between the clay and siliceous material—the former absorbing the dye rapidly and showing characteristic artificial pleochroism, whereas the latter was slightly stained.

A small percentage of iron and aluminium phosphate may be present in the nodules. It is interesting to note that in the brown portion the higher iron content is accompanied by a larger percentage of water which is no doubt present in the limonite.

Among the nodules was one which was very much harder and like unglazed porcelain in appearance. The outer portion, 1.5 cm. thick was pure white, while the interior showed vague banding of dark and pale brown (agate-like). Thin sections showed that it was similar to the other nodules, being isotropic and with less than 2% of free quartz grains.

The white part had a refractive index of $1.605 \pm .003$ and the brown varied from 1.63 to 1.64. Reflected light showed much free limonite in the brown portion. After coarse crushing the white and brown fragments were separated for analysis.

TABLE II.

		<i>a.</i>	<i>b.</i>
SiO_3	...	8.03	3.45
Al_2O_3	...	2.28	3.44
Fe_2O_3	...	1.18	6.64
MgO	...	tr	tr
CaO	...	42.02	41.11
P_2O_5	...	36.0	35.0
$\text{H}_2\text{O}+$	...	3.22	4.25
$\text{H}_2\text{O}-$	...	2.52	1.68
CO_2	...	1.8	2.1
F	...	2.2	2.45
Less O=F		99.25 0.93	100.12 1.03
		98.32	99.09

a. White part of nodule.

b. Brown part of nodule.

Analyst : J. J. F.

In this material there is obviously too little F and CaO to satisfy the amount of P_2O_5 available if the phosphate mineral is fluor-apatite. After allocating sufficient CaO to CO_2 for carbonate and to F for fluor-apatite, there is an excess of CaO which could satisfy some of the P_2O_5 as hydroxyapatite. After the P_2O_5 required for the theoretical amounts in fluor- and hydroxy-apatite indicated by the F and CaO contents is allocated, an excess of 5.7% P_2O_5 in both parts of the nodule remains. There is approximately the required amount of $(\text{Fe}, \text{Al})_2\text{O}_3$ in both types to make up some iron-aluminium phosphate.

X-ray photographs were not as sharp as those of the other nodules and indicated a rather smaller particle size. The (112) and (121) reflection was rather broad and suggested the presence of hydroxy- or more likely hydroxy-fluor-apatite. No other lines, referable to variscite, for example, were observed.

The HCl insoluble residues gave faint montmorillonite type X-ray patterns and the dominant siliceous particles have a refractive index of 1.465 like the above described opal.

The residue from the brown portion contained 78·9% SiO₂ and 6·3% combined water and that from the white 74·9%, SiO₂, and 7·9% combined water.

The brown *phosphatised silcrete* consists of sub-angular and angular quartz grains averaging 0·15 mm. in diameter set in a pale yellow isotropic matrix. In addition there are a fair number of cloudy patches similar in shape and size to the quartz grains but they are isotropic. Some are highly charged with limonite and they were probably original feldspar grains. Interesting evidence of the rhythmic precipitation of iron is furnished by the colloform whorls in the phosphatic matrix. These are strikingly similar to those recorded from Grahamstown and Riversdale silcretes. (Frankel and Kent, 1937).

A heavy residue separated from this phosphatised silcrete was found to consist of euhedral and angular grains of magnetite, rutile, zircon, blue and greenish brown varieties of tourmaline and a trace of garnet. No fluorite was observed. This granite-like and angular grained residue suggests that the silcrete was formed *in situ* from the underlying granite.

The *phosphatised sands* consist of rounded and oval grains of quartz 0·2 to 0·25 mm. in diameter with larger individuals up to 0·5 mm. Many of the grains are cracked and rich in needles of what may be tourmaline. A heavy residue showed an assemblage similar to that found in the silcrete.

CONCLUSIONS.

That the phosphate deposit was essentially sand with clay and calcareous nodules originally (Haughton, 1932), is supported by the evidence given above. Phosphatic solution, in percolating through this deposit converted the limestones and calcareous nodules into (probably) hydroxy-apatite and the argillaceous rock types into aluminium and iron phosphates. The great affinity which fluorine and phosphorus have for each other has led to the adsorption of the former from percolating waters until most of the deposit has been converted into a fluor-apatite in which the fluorine-phosphorus ratio has reached its maximum, although the deposits are still fairly young geologically. A source of fluorine may be found either in the sea or in the granitic rocks of the area.

The presence of such well-defined colloform whorls in the phosphate indicates precipitation of iron and aluminium in an original argillaceous gel now replaced by phosphate or perhaps in the subsequent phosphate. The general tendency for iron and aluminium to be concentrated in the centres of the nodules suggests that these are being leached out towards

the centre and the higher silica percentage in the outer portions indicates silicification inwards. That most of the silica is in the form of opal suggests that the process is still in progress.

ACKNOWLEDGMENTS.

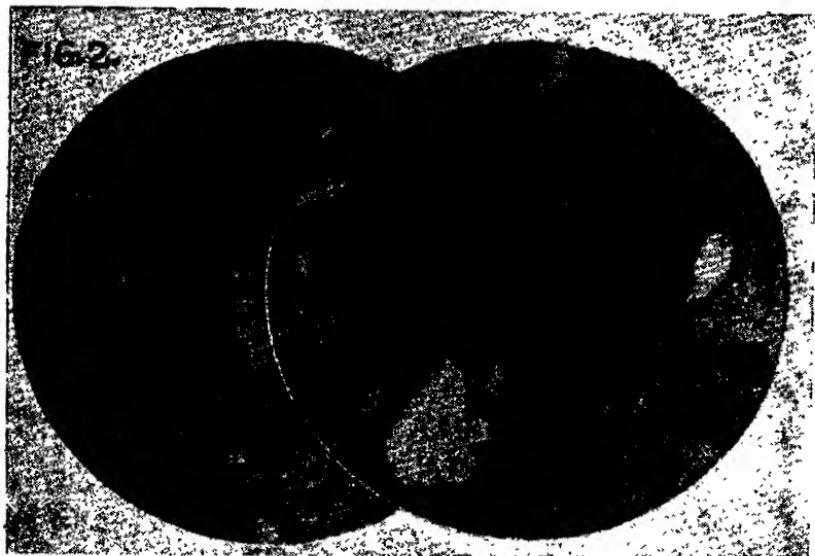
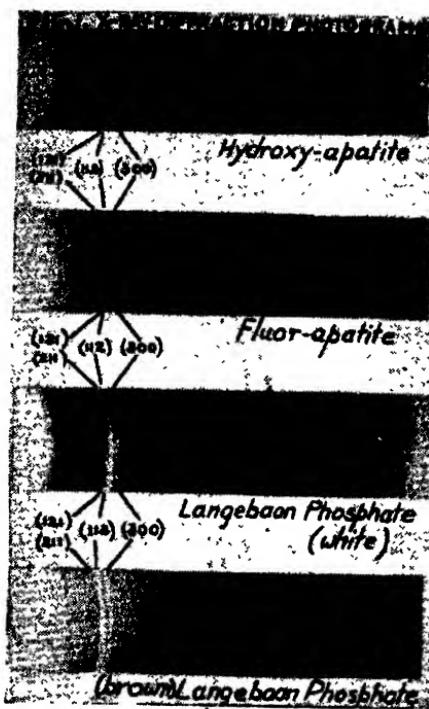
I thank Professor L. Taverner for permission to publish this paper. I am indebted to Mr. L. W. Vermeulen and Mr. J. C. Geertsma for analytical results. Mr. L. H. Ahrens kindly determined fluorine by spectro-chemical methods.

SUMMARY.

By means of chemical analyses and X-ray examination the phosphate mineral present in the Langebaan Road phosphate rock is shown to be mainly a sub-microcrystalline fluor-apatite, with some hydroxy-fluor-apatite and iron and aluminium phosphate. Some of the rock types occurring in the deposit are described and the probable mineralogical changes which have taken place in the formation of the phosphate rock are outlined.

REFERENCES.

- FRANKEL, J. J., AND KENT, L. E.: Grahamstown Surface Quartzites (Silcretes), *Trans. Geol. Soc. S. Afr.* **XL**: 1 (1937).
- HAUGHTON, S. H.: On the Phosphate Deposits near Langebaan Road, O.P. *Trans. Geol. Soc. S. Afr.* **XXXV**: 191 (1932).
- HENDRICKS, S. B., HILL, W. L., JACOBS, K. D., AND JEFFERSON, M. E.: Structural Characteristics of Apatite-like Substances, etc. *Ind. Eng. Chem.* **23**: No. 12, 143 (1931).
- MANSFIELD, G. R.: The Role of Fluorine in Phosphate Deposition. *Amer. J. Sci.* **238**: 863 (Dec. 1940).
- THREWLIS, J., GLOOK, G. E., AND MURRAY, M. M.: Chemical and X-ray Analysis of Dental, Mineral and Synthetic Apatites. *Trans. Farad. Soc.* **35**: 959 (1939).



Photomicrograph of colloform whorls of hydrated iron oxide in phosphatic matrix of phosphatised silcrete. Plane polarised light X25.

SOUTH AFRICAN JOURNAL OF SCIENCE, Vol. XXXIX, pp. 109-111.
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THE EPIDIORITE SILL ABOVE THE ORANGE GROVE QUARTZITES

BY

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Read 29th June, 1942.

A basic sill about 250' thick is intruded into the shales immediately overlying the Orange Grove quartzites in the Central Rand. It is well exposed south of the hills composed of the latter rock. The sill may be traced from Bedford Farm in the east to beyond Melville in the west.

In 1938, blasting operations to the east of Mountain View afforded an opportunity for collecting fresh material for analysis. Subsequently another analysis of specimens from the sill in the vicinity of Melville was made. These specimens are very much fresher than those obtained from Mountain View.

The following are the results of the analyses and the calculated norms.

	1	2		1	2
SiO ₂ ...	51.38	52.09	Q ...	3.90	4.90
TiO ₂ ...	0.38	0.77	or ...	6.62	5.17
Al ₂ O ₃ ...	14.65	15.05	ab ...	12.27	12.11
Fe ₂ O ₃ ...	1.96	1.68	an ...	30.15	32.04
FeO ...	6.13	7.95	di { wo	12.82	9.48
MnO ...	0.14	0.25	en	8.09	5.16
MgO ...	7.41	6.31	fs	3.93	3.99
CaO ...	12.31	11.21	hy { en	10.35	10.55
Na ₂ O ...	1.45	1.43	fs	5.02	8.16
K ₂ O ...	1.12	0.88	mt ...	2.84	2.43
P ₂ O ₅ ...	0.03	0.12	il ...	0.89	1.44
H ₂ O+ ...	2.42	1.97	ap ...	0.07	0.32
H ₂ O— ...	0.03	nil	cm ...	0.11	—
S ...	0.12	0.12	pr ...	0.22	0.22
Cr ₂ O ₃ ...	0.07	0.02			
CO ₂ ...	0.02	—	Specific Gravity	2.97	3.03
	99.62	99.85			

Analyst J.J.F.

Chemically the rock is a typical diabase. With the exception of a lower iron percentage in the Mountain View

specimens the rocks show little variation in chemical composition.

At both localities the basal part of the sill is rather like a medium-grained gabbro in appearance and coarser than the centre or the top which are typically diabasic in grain size.

Under the microscope, however, the rocks from the two localities are dissimilar. The Mountain View specimens from all parts of the sill are rich in saussurite and sericite and contain only small amounts of fresh original feldspar which was determined as andesine (An_{48}). Although lath outlines of the original feldspars are often well-preserved almost complete replacement by granular epidote has taken place. Some clearer laths are oligoclase (An_{18}) and are probably the result of albitisation. Uralitic amphibole has almost completely taken the place of pyroxene. Occasionally the alteration has been partial and cores of pyroxene are preserved which are slightly pleochroic and found to be augite ($2V\gamma 48^\circ$). The green pleochroic amphibole has $2V\alpha 88^\circ$ and $\gamma 1.640 \pm .003$. Chloritisation of the amphibole has also taken place.

An alteration product with apparently straight extinction has low interference colours and $2V\alpha 78^\circ$. It has been suggested that it may be bastite (McDonald, 1911); but it is not easy to decide whether it is derived from the pyroxene or the subsequently formed amphibole. Colourless epidote with α and $\beta 1.720 \pm .003$, $2V \alpha 86^\circ$ and very low interference colours, occurs as euhedral grains up to 0.15 mm. across. This mineral is obviously on the boundary between epidote and clinozoisite. Secondary and original quartz, ilmenite almost completely altered to leucoxene and pyrite are the other minerals present. Only small amounts of micrographic intergrowths of quartz and orthoclase were observed.

The basal part of the sill contains amphibole crystals up to 4 mm. long and generally all the minerals are of larger grain size than in the rest of the sill. Only a little quartz is present and micrographic intergrowths are scarce. There seems to be a definite increase in the amount of quartz in the upper parts of the sill.

In the vicinity of Melville the sill is of a darker green colour which is due to the presence of broad prisms of amphibole. In thin section the rock is seen to be composed of fairly fresh orthoclase and labradorite (An_{ss}), the bulk of which is saussuritised. There are more free quartz grains and micrographic intergrowths of quartz and orthoclase than in the specimens from the eastern area. The amphibole is present in twinned laths 1.3×0.3 mm. which are often curved. Uralitisation appears to be more complete in this rock. In addition, there is much leucoxene containing very little of the original ilmenite. The colourless epidote is similar to that described above, but tends to be concentrated in small

clusters of larger crystals. Much finer granular epidote, chlorite, sericite and pyrite are also present.

Near Mountain View a poorly exposed dyke running N-S and about 60' wide cuts through the Ventersdorp lavas and the underlying Witwatersrand rocks (McDonald, 1911). The outcrop disappears as the sill is approached and it is therefore not known whether the two bodies link up. Mineralogically the rocks are very similar, except that a pale yellow epidote with high interference colours is also present in the dyke. In texture the dyke rock is sub-ophitic.

It is reasonable to assume that the two bodies are of the same age, i.e. post-Lower Ventersdorp, but it is impossible to state whether they are genetically related to the diabase intrusions of Bushveld age.

The mineral assemblage of the rocks indicates that dynamic metamorphism has converted what were originally typical diabases into epidiorite.

ACKNOWLEDGMENTS.

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SUMMARY.

The basic sill intruded into the shales above the Orange Grove quartzites in the Central Rand is shown on analysis to be a typical diabase. The mineral composition which is described indicates that dynamic metamorphism has converted the rock into an epidiorite.

REFERENCE.

McDONALD, D. P.: The Intrusive Rocks of the Witwatersrand. *Trans. Geol. Soc. S. Afr.* XIV: 89 (1911).

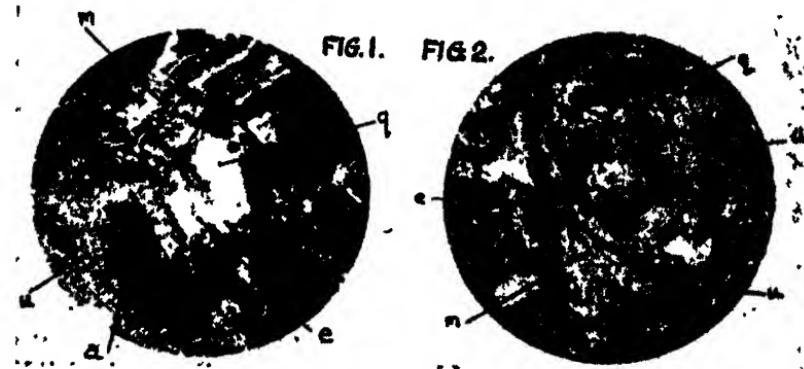


Fig. 1. Photomicrograph of sill from Mountain View to illustrate incomplete urallisation of pyroxene. Core of augite (a) surrounded by uralite (u) coarse epidote (e), quartz (q) and micrographic intergrowth (m) of quartz and orthoclase present. Crossed nicks X20.

Fig. 2. Photomicrograph of sill from Melville area in which trimmed uralite (u), quartz (q), granular epidote (e) and micrographic intergrowth (m) of quartz and orthoclase are visible. Crossed nicks X15.

SOUTH AFRICAN JOURNAL OF SCIENCE, Vol. XXXIX, pp. 112-115.
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THE THIRD SPECIES OF ATALAYA IN SOUTH
AFRICA—ATALAYA NATALENSIS SP. NOV.

BY

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Read 29th June; 1942.

The genus *Atalaya* was first recorded in South Africa by the writer⁽¹⁾ in 1937 when *A. capensis* was described. It was the subject of a second paper in 1939 when Forbes⁽²⁾ pointed out that the plant described by Sim⁽³⁾ in 1909 as *Diacarpa alata* should also be referred to the genus *Atalaya*. Only two years later again, the third species is recorded. Even taking the date of 1909, when *Atalaya alata* (Sim) Forbes was first described, as the first record of the genus in Africa, the subsequent two discoveries in such a short space of time and at such a late stage of botanical exploration in South Africa, are none the less noteworthy.

The third species, which I propose to name *Atalaya natalensis*, was brought to my notice in February, 1942. The Chief Forest Research Officer forwarded flowering material collected by the forester L. Joubert, at Ngomi, Natal, to the National Herbarium, Pretoria, for identification. It was stated that it was a tree about 40 ft. high with a diameter breast high of about 12", growing in high forest. The forester further recorded that the tree seems to be partially deciduous, occurs only on soil mixed with large boulders and rocks, and that reproduction is abundant near the parent tree in the form of seedlings. On 28th March, 1942, the forester at Ngomi collected fruiting material and gave the following additional information: "Specimens are found above and below krantzes inside the forests, the aspects being east and south-east. Only in one instance have I found specimens away from the krantzes on a rocky ridge with a south-eastern aspect, and at one place in the forest above the krantzes among large boulders where the soil was invisible under the boulders. The species appears abundantly with very few trees of other species present." If the tree is abundant and regenerates freely from seed in the Ngomi forests, one wonders why its general distribution should be as restricted as it seems to be.

A. natalensis is more nearly related to *A. capensis*, from the eastern Cape Province, than it is to *A. alata*, which is far nearer in distance, being recorded from Portuguese East Africa and Zululand. It is the largest of the three species and is further distinguished by the shape and size of the leaflets and samaras—Fig. 00. The floral structure is very similar to that of *A. capensis* as illustrated in 1937⁽¹⁾.

As with other similarly winged fruits, the samaras gyrate when they fall to the ground. The shape of the scar on each samara left by the splitting up of the fruits, indicates whether one, two or three of the carpels matured. If only 1 developed the scar is concave, if 2 the scar is straight and nearly flat, if 3 it is straight and slightly 2-angled.

Equally interesting in the family *Sapindaceae* is the recent record by Verdoorn⁽⁴⁾ of the second species in South Africa in the genus *Erythrophysa*, namely *E. transvaalensis*. One calls to mind also such diverse forms of fruits as occur in the genera *Cardiospermum*, *Smellophyllum*, *Pappea*, *Dodonaea* and *Hippobromus*. The specialised fruit characters and the comparatively limited distribution of several species encourages speculation on the trend of evolution in the family as a whole; whether these unique forms are recently evolved or relictions of a bygone abundance. The latter suggestion seems the more probable, but undoubtedly there is here a profitable field for investigation.

DESCRIPTION:—* A tree up to about 12 m. high, with a trunk about 30 cm. in diameter breast high, partially deciduous; branchlets leafy and furnished with lenticels, glabrous. Leaves paripinnate; the rhachis 6-12 cm. long, and sometimes produced slightly beyond the last pair of leaflets, glabrous; leaflets in 3-5, rarely only 2 pairs, usually opposite, but not always strictly so; petiolule about 5 mm. long; blade 5-8.5 cm. long, 1.5-2.5 cm. broad, elliptic- or oblong-lanceolate, acuminate, often slightly asymmetric, margin entire, usually slightly undulate; venation moderately prominent on both surfaces. Inflorescence densely paniculate; panicles terminal or in the axils of the upper leaves, usually longer than the subtending leaves, glabrous. bracteate; the bracts about 3 mm. long, lanceolate; pedicels slender, up to 5 mm. long. Sepals 5, imbricate, up to 3.5 mm. long, 3 mm. broad, the outer ones smaller, suborbicular, ciliate; the inner face concave. Petals slightly smaller than the inner calyx lobes, shortly stipitate, pilose on the back, more densely so towards the base, sparsely pilose on the inner face and furnished with a hirsute appendage from above the stipe, ciliate, more densely so towards the base. Disc fleshy, expanded at the base and enclosing the base of the filaments. Stamens 8, filaments inserted within the disc, sparsely pilose.

Ovary 3-celled, with 1 ovule in each cell, narrowly winged; style short. *Fruit* 1-3-winged, usually one or two carpels being partially aborted; the winged carpels or samaras, asymmetric with the upper margin nearly straight and the lower one falcate in outline, 4-5-5 cm. long, 1.75-3 cm. broad, rigid, prominently veined, 1-seeded, indehiscent, glabrous within the seed chamber; seed 5-6 mm. long and up to 4 mm. broad, hard, brown.

Distribution:—Natal: Vryheid district, Ngomi forest, Joubert in National Herbarium, Pretoria, No. 26805 (Jan. flowers) 26811 (Mar. fruit).

* *Atalaya natalensis* R.A. Dyer, sp. nov. affinis *A. capense* habitu majore foliis longioribus samaris majoribus differt. *Arbor* usque 12 m. altus. *Folia* paripinnata rache 6-12 cm. longo; foliola 3-5-jugata, 5-8.5 cm. longa, 1.5-2.5 cm. lata, elliptico-vel oblongo-lanceolata, acuminata. *Paniculae* foliis breviores vel longiores. *Sepala* interiora circiter 3.5 mm. longa, 3 mm. lata exteriora minora. *Petala* sepalis interioris minor, breviter stipitata, intra pilis paucis et squama hirsuta instructa. *Discus* carnosus, subcateriformis, margine undulato, plus minusve expanso. *Stamina* 8, intra discum inserta, petalis longiora. *Ovarium* 3-loculare, triquetrum; stylus brevis. *Fructus* 1-3-alatus, plerumque 1-2 samaris abortivis; samarae 4-5.5 cm. longae, 1.75-3 cm. latae, intra loculo glabro usque 1.2 cm. longo.

BIBLIOGRAPHY.

1. DYER, R. A.: *Atalaya capensis*. A New Generic Record for South Africa. This Journal 34, 214-217 (1937).
2. FORBES, H. M. L.: A Further Record of the Genus *Atalaya* in South Africa. This Journal 38, 314-315 (1939).
3. SIM, T. R.: Forest Flora of Portuguese East Africa, p. 33 (1909).
4. VERDOORN, I. C.: *Erythrophysa transvaalensis* sp. nov. in Flowering Plants of South Africa, 21 plates (in press).



Fig. 04. 1, Leaflets; 1a, fruit (samaras) of *Atalaya natalensis*; 2 and 2a, *A. Alata*; 3 and 3a, *A. expansis*; (all average life size).

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A COMPARISON OF COMPOST AND INORGANIC FERTILISERS AS TOP DRESSING FOR ESTABLISHED PASTURE

BY

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Read 30th June, 1942.

INTRODUCTION.

Concerning the benefits to soils and crops of such organic dressings as kraal manure and composts, especially when used in conjunction with phosphates, as stressed by Orchard (1939 : 23) and Timson (1939 : 803) there is no question. Can compost be used, however, to the best advantage economically as a pasture top-dressing? Orchard (1939 : 25, 26) mentions that few, if any, scientific experiments have been carried out to test the value of compost in the field, and opines that if it is used as a top-dressing for established pastures, there is no doubt that a considerable amount of nitrogen will pass into the atmosphere, particularly if spreading is not performed on a rainy day. Pole-Evans (1938 : 522) reports that at the Athole Pasture Research Station, Preller found 5 tons of compost per acre on natural pasture had very little effect, and he concludes that compost must be incorporated in the soil to be beneficial and must not be considered as a source of nitrogen for top-dressings. This is in marked contrast with the great volume of world-embracing evidence recording the almost infallible benefit from inorganic nitrogenous top-dressings on established and natural pastures. We have ourselves submitted such data regularly in this Journal from 1931 to 1940. The results of the Dohne Research Station as reported by Pole-Evans (1938 : 504) record that fertiliser applications not only increased the yield of grass but also gave a better increase in animal weights. These observations are in accord with our own data reported in this Journal (1940 : 111-129).

As regards crop response to compost applications, much has been written of a popular and propagandist nature and Orchard (1939 : 25) points out that in many cases the merits claimed for compost are rather extravagant. McMartin, in discussing a paper by Ingham (1941 : 75) goes as far as to say that many people consider the words, compost, humus, and magic as synonymous.

Object of the Experiment. Because of this almost fanatical attitude to compost by some officials and farmers,

in which its benefits are attributed to organic matter, humus, micro-organisms, mycorhiza, hormones, and rarer elements, with little reference to the large amounts of nitrogen, phosphoric oxide, potash and lime which five and ten ton dressings put in the soil, we decided to compare large dressings of compost, of which the composition was known, with applications of mineral fertilisers supplying the equivalent of at least the nitrogen, phosphoric oxide and potash. Benefits or yields over and above those produced by the equivalent fertility plane could then be assigned to the other factors.

Method of Experimentation and Technique. An area of established pasture, as uniform as possible, in a camp at the Frankenwald Botanical Research Station, was selected for experiment. The portion of the camp picked had been planted to alternate rows of the Pongola strain of Finger Grass (*Digitaria eriantha*) and *Digitaria smutsii*, in February and March, 1935. The tufted latter type was not able to compete with the stoloniferous Pongola strain, however, and when this experiment was put down, it was a pure stand of *Digitaria eriantha*.

The area was measured and pegged off in October 17th, 1938, in the form of a 4 x 4 Latin square with $\frac{1}{100}$ th acre plots. Plots Nos. 1, 2, 3 and 4 were the first row across and 1, 5, 9 and 13 the first row down. Paths three feet wide were left untreated between the plots. There were four replications of each treatment which were as follows, in tons and lb. acre.

- A. 4.4 tons animal compost and 152 lb. rock and superphosphate mixture.
- B. 191 lb. ammonium sulphate and 200 lb. rock and superphosphate plus 68 lb. potassium chloride.
- C. 10 tons animal compost.
- D. 433 lb. ammonium sulphate and 110 lb. rock and superphosphate plus 154 lb. potassium chloride.

These treatments provided per acre, in lbs., the following constituents:—

	N ₂	P ₂ O ₅	K ₂ O
For A and B each	40.2	48	40.8
For C and D each	91.3	26.4	92.6

This soil type, on old grey granite, has been previously described in this Journal (1937: 277).

The animal compost was spread on the organic plots on October 28th, 1938, and the inorganic fertilisers, including the rock and superphosphate, on the A plots on November

8th, 1938. In treatment D, only half the nitrogen was applied at this time and half the balance, i.e. one quarter of the original amount planned, due on these plots on February 3rd, 1938. Thus these D plots received only $\frac{1}{4}$ of the amount of nitrogen originally planned and one quarter was left over until the next season.

On the 23rd and 24th January, 1939, the paths between the plots were cut by hand and then on February 2nd, 1939, the plots were mown with the mowing machine. No grass was carried over from one plot to another and what grass fell on the paths was raked back to the respective plot by hand. The hay was air-dried and weighed and representative samples were taken for chemical analysis. This procedure was followed after every mowing.

On April 17th, 1939, the plots were mown for the second time, the paths having previously been mown by motor lawn mower.

In the 1939-40 season, the plots were mown, after the paths had been cut by hand, for the first time on January 15th, 1940. On January 17th, 1940, the D plots were given the final ammonium sulphate dressing, thus completing the application of 91.3 lb. nitrogen per acre. The final harvesting of all plots took place on April 1st, 1940, after which date the experiment was discontinued.

TABLE I
Dry Matter Yields in lb per acre

Season 1938-39					Season 1939-40			
Plot No	Treatment	First cut	Second cut	Total	First cut	Second cut	Total	Total for four cuts
1	A	865	819	1684	333	340	673	2357
2	C	919	455	1374	214	231	445	1819
3	B	1984	710	2694	105	211	316	3010
4	D	1784	1755	3539	499	468	967	4506
5	B	1784	637	2421	228	169	317	2818
6	D	1329	1410	2739	181	352	543	3272
7	C	919	300	1219	109	151	260	1479
8	A	865	182	1047	119	104	223	1270
9	C	919	209	1128	152	143	295	1423
10	A	610	164	774	114	88	202	976
11	D	1474	1548	3022	109	264	373	3395
12	B	1430	801	2231	95	691	186	2417
13	D	1374	1210	2584	456	428	884	3468
14	B	1072	546	1618	95	130	225	1843
15	A	355	46	401	52	74	126	527
16	C	410	91	501	71	98	169	670

These data were examined statistically according to the method described by Saunders (1935: 29) and gave a Z value of 2.6076. As the required value for the 1% probability is 1.1401, the odds are well over 100 to 1 in favour of a significant treatment effect. With regard to significant differences between treatments, it was found that any difference between the average treatment yields should exceed 286 lb. dry matter. At this figure the low fertiliser treatment B is significantly better than the low compost A, and furthermore is also better than the high compost treatment C. There is no significant difference between the high and low compost treatments. The high fertiliser treatment D, is significantly better than all the other treatments. For the 1939-40 totals, the figure corresponding to 286 lb. is 166 lb. between means of treatments. This shows that in the second year there is no significant difference between high and low compost or low fertiliser and compost as far as residual effect is concerned, but that the high fertiliser treatment D is highly significant over all the other treatments A, B and C. The means for comparison are given in Table II.

TABLE II.

Means for Treatments, lb. per acre Dry Matter.

Treatments.	1938-39.	1939-40.	Total for all 4 cuts.
A. Low compost ...	977	308	1285
B. Low fertiliser ...	2241	281	2522
C. High compost ...	1056	292	1348
D. High Fertiliser ...	2971	689	3660

- Knowing now that the experiment has yielded reliable and significant data, we shall proceed to study the summarised analyses of the dry matter.

TABLE III.

Per Cent. Composition of Hay, Season 1938-39, 1st Cut February 2nd, and 2nd Cut April 17th, 1939.

Treatment.	Crude Protein.		Phosphoric Oxide.		Potash.		Lime.	
	1st cut.	2nd cut.	1st cut.	2nd cut.	1st cut.	2nd cut.	1st cut.	2nd cut.
A l.c. ...	4.49	4.21	0.53	0.61	1.54	1.48	0.80	0.55
B l.f. ...	4.99	3.50	0.42	0.47	2.25	1.91	0.77	0.51
C h.c. ...	4.37	4.18	0.51	0.57	1.69	1.51	0.75	0.58
D h.f. ...	4.97	3.62	0.37	0.38	2.29	2.21	0.75	0.50

TABLE IV.

Per Cent. Composition of Hay. Season 1939-40. First cut January 15th second cut April 1st, 1940.

Treatment.	Crude Protein.		Phosphoric Oxide.		Total Soluble Ash. • 1938-39.	
	1st cut.	2nd cut.	1st cut.	2nd cut.	1st cut.	2nd cut.
A l.c. ...	4.12	4.12	0.61	0.68	3.48	3.27
B l.f. ...	4.00	4.18	0.58	0.68	4.39	3.63
C h.c. ...	4.56	4.06	0.70	0.73	3.71	3.41
D h.f. ...	3.87	4.93	0.57	0.62	4.45	4.06

Observation on the Percentage Composition of Hay over Two Years:

Crude Protein. The percentage figures are disappointingly low, considering the heavy dressings of compost and fertiliser which the plots received. This is no doubt due to the growth habits of this Pongola strain of Digitaria, which although vigorous and aggressive and closely covering the ground, is very stemmy above the height at which the mower cuts. Rhodes grass hay from an adjacent camp, sampled for analysis at the same time in the second season, gave crude protein content of 11.81% and phosphoric oxide 0.72%. The compost plots, although producing lower yields of hay, maintained a better crude protein content in the second cut of the first season, and were also somewhat higher in the first cut of the second season. For the second season the protein as a whole is slightly better in the second cut. The yield was, however, much smaller than the previous year and the last cutting sixteen days earlier, the difference therefore may be only seasonal.

The dressing of ammonium sulphate given the D plots, on January 17th, 1940, is undoubtedly shown up on the April cut.

Phosphoric Oxide. The hay from the compost plots has on the whole a somewhat better phosphoric oxide content than that from the plots receiving inorganic fertilisers. This is particularly noticeable with regard to the D plots. The B plots which received nearly twice as much inorganic phosphoric oxide as the D plots, also show a superior content to the D plots the first year, the small difference the second year may not be significant.

Potash. These determinations were made only the first season. The potash content of the hay from the plots getting the inorganic fertiliser, is, however, markedly superior to that for the compost ones in both cuts.

Lime. The nature of the dressing does not appear to have affected the lime content of the hay in any way. There is, however, a more rapid drop in percentage by the second cut than for the three constituents previously mentioned.

Total Soluble Ash. The hay from the plots getting the inorganic fertilisers has a higher content, particularly for the first cut.

When the yield of total fertility constituents is studied on an acre basis, the conclusions arrived at are somewhat different.

TABLE V.

Yields of Constituents in lb. per acre.

Treatment	Crude Protein			Phosphoric Oxide			Potash and Lime.	
	1st year.	2nd year	Total.	1st year.	2nd year	Total	Potash.	Lime.
A Low compost	44.4	13.1	57.5	5.5	1.8	7.3	14.5	7.2
B Low fertiliser	101.9	11.3	113.2	9.9	1.8	11.7	47.9	15.8
C High compost	46.2	13.1	59.3	5.6	2.1	7.7	17.2	7.6
D High fertiliser	128.8	30.6	159.4	11.3	4.0	15.3	67.4	18.9

The superior results from the inorganic fertiliser dressings over those of the compost are strikingly shown when compared on a basis of returns per acre. This applies particularly to the two year results for crude protein and phosphoric oxide, substances of importance for body building, and finishing off steers. The figures for crude protein, phosphoric oxide, potash and lime all reveal that the ten ton dressing of compost has been of no greater value than 4.4 tons of compost reinforced with 152 lb. per acre of a mixture of superphosphate and rock phosphate. This is also reflected

in the total yields given in Table II which are remarkably similar for the two compost dressings.

TABLE VI.

Percentage Recovery of Nitrogen

Treatment	lb. Nitrogen applied per acre over two years.	First year		Both years.	
		lb nitrogen.	Percentage return	lb nitrogen	Percentage return.
A Low compost	40.2	7.1	17.6	9.2	22.9
B Low fertiliser	40.2	16.3	40.5	18.1	45.0
C High compost	91.3	7.4	8.1	9.5	10.4
D High fertiliser	91.3	20.6	30.1	25.5	27.9

This table shows that the low compost dressing has been over one hundred per cent. more efficient than the high dressing as far as nitrogen recovery is concerned and also that the low inorganic dressing has been markedly superior to the high fertiliser one and to both compost dressings. The low fertiliser dressing has in fact given the best recovery of nitrogen.

DISCUSSION.

The poor fertility of this soil on the old grey granite is strikingly shown in the low yields obtained in the second season on plots A, B and C. Only in the case of the high inorganic fertiliser D does there appear to be any residual effect. The application of 108 lb. ammonium sulphate after the first cut of the second season increased the yield a further 21.4% however. In the first season the rainfall from October, 1938, to the end of March, 1939, was 25.84 inches. For the same period in the 1939-40 season it was 25.03 inches. In both seasons the rainfall was fairly well distributed and the driest months were January in both seasons with 2.32 and 1.80 inches respectively. At no time in this experiment did the pasture, therefore, suffer from drought.

A study of Tables II and V shows that on this soil type, there is remarkably little difference between the returns from low and high compost dressings and in fact the yields of dry matter, crude protein and P₂O₅ in both seasons are almost identical. Also in the case of the lime content of the herbage in the first year, there is practically no difference and only in the case of the potash content in the first year is there a small increase in yield over that of the low compost dressing. The nutrients in compost were evidently less available to the grass than those of the inorganic fertilisers, for it will be

seen that the returns of all constituents were higher from the low inorganic fertiliser than from the high compost dressing. In fact, the total yields of dry matter, crude protein and lime were approximately twice and that of potash nearly three times those of the high compost dressings.

It is clear that the yields of plant food constituents and of dry matter are considerably higher in the case of the high inorganic fertiliser dressings than in the high compost treatment, which delivered the same amounts of plant food. It seems that under the conditions of this experiment a more efficient return of nutrients from pasture grasses will be obtained with inorganic fertilisers than with compost and that pasture grasses have not responded to plant food in this organic form.

With regard to the recovery of the nitrogen applied, this was most efficiently done from the low inorganic dressing, which was 400 per cent. better than the high compost, and even the high inorganic dressing gave a better percentage recovery of nitrogen than the low compost. The heavy dressing of compost has been shown to be a most wasteful means of applying nitrogen to pastures. The fact that both the low compost and low inorganic fertiliser dressings had a better phosphate content might also have influenced the nitrogen uptake as it is an acknowledged fact among agronomists that bulky organics like animal manure and composts supplemented with phosphates give far better crop yields than an equal quantity of the organic alone.

The results indicate that, even as regards inorganic nitrogen, too much must not be given at one time and the smaller amounts applied more often will probably give better results and are likely to be much less wasteful.

Russell and Watson (1940) report that on the Broadbalk field at Rothampstead, one of the most striking features of the results was the predominant effect of synthetic nitrogenous fertilisers on yield. Sodium nitrate and ammonium sulphate were about equally effective but the nitrogen in farmyard manure was only half as effective. The recovery of the nitrogen in sodium nitrate was about thirty-five per cent., while that of farmyard manure was only fifteen per cent. From arable land which is admittedly more favourable for bulky organics; the data therefore substantiate our own on pastures.

CONCLUSIONS.

From the data here presented, it appears that on this soil type and established grass (*Digitaria eriantha*), better responses are obtained in yield of dry matter, crude protein and minerals from applications of inorganic fertilisers than

from animal compost. It follows therefore that if compost is available it would be more efficiently used on arable crops, rather than on grassland, which by virtue of its relatively denser cover and extensive root system, is able to increase the humus content of the soil without additions of organic forms of plant food.

SUMMARY,

- (1) In order to ascertain the fertility value of animal compost, a Latin square experiment was laid down, in which four replications of each of four treatments were compared. Two treatments were organic and two inorganic and they were compared on the basis of equal amounts of nitrogen, phosphoric oxide and potash.
- (2) The standard of results was yields of dry matter, also analysed for their nitrogen and mineral content, produced from an established pasture of the Pongola strain of finger grass (*Digitaria eriantha*) growing on soil over old grey granite at the Frankenwald Botanical Research Station.
- (3) A statistical examination showed the results to be reliably significant and that the low inorganic dressing was better not only than its low compost counterpart, but also than the high compost, and that the high inorganic dressing was significantly better than all the other treatments. There was no significant difference between high and low compost dressings.
- (4) As far as the nitrogen and mineral content is concerned, the hay from the compost plots held its own on a percentage basis and was on the whole better in its phosphoric oxide content; in potash content, however, the hay from the inorganic fertiliser plots was markedly superior. When the production of crude protein and minerals is compared on an acre basis, however, the plots getting inorganic fertilisers are much superior in total yields, with the high inorganic figures well ahead of the low, whereas the low and high compost yielded about the same amount of these ingredients, showing that 4·4 tons per acre of animal compost, supplemented with 152 lb phosphates were a more efficient dressing than 10 tons of pure animal compost.
- (5) The low dressing of inorganic fertilisers gave much the highest percentage recovery of nitrogen, i.e. 45 per cent. compared with only 10 per cent. from the high compost. The low compost was over a hundred per cent. more efficient than the high compost dressing in this respect while the low inorganic was 62 per cent. more efficient

in the ultimate recovery of nitrogen than the high inorganic fertiliser dressing. It would appear then that smaller dressings at more frequent intervals would be more effective in hay production. To what extent a better phosphate balance in the lower dressings influenced the uptake of nitrogen is not known, but it should be determined sometime, as it is a well-known fact among agronomists that bulky organic dressings supplemented with phosphates, give higher yields, than such dressings used alone.

REFERENCES.

- EVANS, I. B. POLE: An. Report Div. of Plant Industry. *Farming in S.A.* Vol. 13: 522 (1938).
- HALL, T. D., MEREDITH, D., AND MURRAY, S. M.: The Productivity of Fertilised Natural Highveld Pastures. This Journal. 34: 275-285 (1937).
- HALL, T. D., MEREDITH, D., ANN MURRAY, S. M.: Fertilising Natural Veld and its Effect on Sward, Chemical Composition, Carrying Capacity and Beef Production. This Journal. 37: 275-285 (1940).
- INGHAM, G.: Organic Manures, Composts, and Artificial Fertilisers, Proc. 15th An. Cong. S.A. Sugar Tech. Assoc. 70-77 (1941).
- ORCHARD, E. R.: Compost: Its Preparation and Use. Dept. of Agric. and Forestry. Sc. Bull. No. 201 (1939).
- RUSSELL, E. J., AND WATSON, D. J.: The Rothamstead Field Experiments on the Growth of Wheat. Tech. Com. No. 40. Imp. Bur. Soil Sc. (1940).
- TIMSON, S. D.: Compost. *Rhodesia Agric. Jour.* 36. 10: 740-752. 11: 791-813. 12: 860-883 (1939).

AGRICULTURAL DEVELOPMENT IN THE COAST PROVINCE OF KENYA

BY

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THE DOWNWARD MOVEMENT OF SAP PRODUCED BY RAPID KILLING OF THE LEAVES

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Read 29th June, 1942.

INTRODUCTION.

The theory that the xylem normally acts as a channel for the downward movement of solutes, though still upheld by some, is not widely accepted to-day. It is, however, well established that a downward flow through the xylem may result from abnormal conditions such as occur during injection experiments (Curtis 1935). Kennedy and Crafts (1927) were the first to suggest that a downward movement through the xylem might occur as a result of killing the leaves by spraying the plant with certain chemicals. The use of a dilute solution of sulphuric acid and sodium arsenite has sometimes rendered possible the destruction of certain deep-rooted perennial weeds, and as this type of weed is usually one of the most troublesome, the theory has important practical applications.

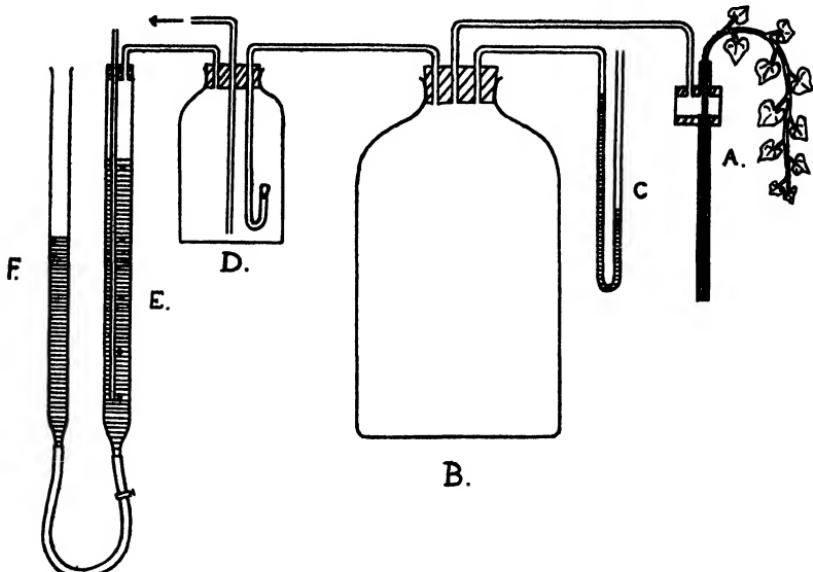
The theory of Crafts and Kennedy is fully stated in an article published in 1930. It points out that in accordance with the theory of Dixon (1914), active transpiration of a plant sets up a reduced pressure within the vessels, the walls of which contract, and that if a solution under atmospheric pressure is released into the xylem, a rapid uptake will occur until the vessels have reached their normal capacity. Thereafter a slower osmotic absorption by the living cells will continue till all deficit is satisfied.

From these facts Crafts and Kennedy then conclude:—

“Therefore, when an extremely toxic spray is applied to the leaves and stems of a morning-glory plant and the tissues rapidly killed, the sap which they contain, mixed with more or less of the toxic spray solution, will pass into the xylem vessels and be forced down toward the roots.”

The evidence in favour of the theory of Crafts and Kennedy will be considered under the heading “Discussion and Conclusions.” It may be stated here, however, that as much of this evidence can to a large extent also be explained on some other basis, an attempt was made in the present

investigation to obtain evidence subject to no other interpretation. It was hoped to accomplish this by an experimental demonstration of the occurrence of a downward flow through the xylem, after the leaves of the plant had been sprayed.



APPARATUS.

A diagram of the apparatus is shown in the accompanying figure (A), the container for the stem, consisted of a short, wide piece of glass tubing through which the stem was passed into a long graduated tube containing water. In measuring the amount of water absorbed by or drawn back from the branch, allowance for the displacement of the stem had to be made. As uniform stems were used, no great error resulted. The container for the stem was connected to a large jar (B), of capacity 20 litres, which served the purpose of a reservoir. The pressure of the air within the system was measured by means of a manometer (C) connected to this reservoir. The latter also communicated with a smaller jar (D), from which backward flow of air into the reservoir was prevented by means of a glass valve. This jar in turn was connected to a suction pump as well as a pressure-regulating device. This device consisted of a long tube containing mercury, into which dipped one end of a piece of glass tubing, the other end being open to the atmosphere. The pressure, therefore, within the system reached a constant level, after the suction pump had reduced it sufficiently to result in air bubbles being drawn up through the mercury. If the suction developed by the pump increased, the bubbling became more rapid, and hence the pressure of the air within the system was but very slightly affected. If, owing to temporary failure of the water supply the pump failed to function effectively for a time, no more air was drawn in through the mercury; owing to the large reservoir the pressure within the system altered but slightly, even though, as was usually the case, bubbles of air were being drawn in through the cut end of the stem. By raising or

lowering an attached levelling tube (E), the mercury within the long tube could be made to rise or fall, and the pressure within the system thereby adjusted to a convenient value. The levelling tube when not in use was disconnected from the apparatus by means of a screw clip.

The advantage of this type of apparatus was that the pressure of air within the system was not affected by the bubbles of air that were usually drawn in through the cut end of the stem. Earlier types of apparatus had had to be discarded owing to this difficulty.

RESULTS.

In this investigation material of *Ipomaea purpurea* Roth was used as it was more readily obtainable than that of *Convolvulus arvensis* L., employed by Crafts and Kennedy in their experiments. The rate at which water was absorbed by or drawn back from the plant was expressed in ccs./gram dry weight of laminae/hour, as the killing of the leaves during the course of an experiment rendered impossible the expression of results in terms of leaf area.

(a) Control experiment.

In order to test whether the plant was in any way adversely affected by the experimental conditions, a control experiment was performed, during which the pressure within the system was maintained at 30 cms. of mercury less than atmospheric. The results of this experiment (carried out on two different branches of *Ipomaea purpurea*) are given in Table I. Neither stem showed any signs of wilting, nor gave any other indication whatsoever of suffering from lack of water.

From Table I (see end) it will be seen that although there was a decrease in the rate of water absorption during the night, 25 hours after the commencement of the experiment the branches had either regained, or very nearly regained, their initial rate of water absorption. It can therefore be concluded that the apparatus itself did not have a seriously adverse effect upon the branches subjected to experimental conditions. The pressure within the system in all subsequent experiments was always maintained at 30 cms. of mercury less than atmospheric.

(b) Acid-arsenical spray.

In this experiment a branch of *Ipomaea purpurea* after being placed in the apparatus was sprayed with a solution similar in composition to that employed by Crafts and Kennedy, although arsenic pentoxide was used in place of arsenic trioxide dissolved in caustic soda solution. The spray solution used in this experiment contained 5 per cent. sulphuric acid (S.G. 1.84) by volume and 3 per cent. arsenic pentoxide by weight. The results of this experiment are

given in Table II (A). It will be seen from the table that the branch continued to absorb water for some time after it had been sprayed, though the rate of absorption declined fairly rapidly. Within just over an hour after the branch had been sprayed, a backward flow of sap from the leaves into the container from the stem had commenced. The rate at which the sap was drawn back at first gradually increased, then later remained practically constant over a five-hour period, and finally became somewhat irregular. The effect of the spray solution upon the leaves was to result in a rapid loss of turgidity followed by their complete collapse and death. This experiment was repeated several times and in each case similar results to those given above were obtained, though usually there was a more marked decline in the rate at which sap was drawn back once the maximum had been reached. As it has already been shown that the pressure to which the stem was subjected did not in any way harm the branch, and as such a pressure can be expected to occur within the vessels of an uncut plant under natural conditions, strong evidence in favour of Crafts and Kennedy's theory is supplied by the above experiment.

(c) *Sulphuric acid spray.*

In Table II (B) (see end) are given the results of an experiment in which a branch of *Ipomoea purpurea* was sprayed with a 5 per cent. (by volume) sulphuric acid solution. It will be observed that though the plant absorbed water at a fairly high rate during the first ten minutes, all upward movement ceased after this, and during the following hour there was no movement either into or out of the branch. After this, a backward flow occurred, gradually increasing to a maximum and then later falling off. It is therefore evident that the incorporation of arsenic pentoxide in the spray solution is not essential for the production of this phenomenon. This again is in agreement with the views of Crafts and Kennedy, who state that the purpose of using arsenic in the spray solution is to destroy the tissues with which it comes into contact; whereas sulphuric acid is incorporated into the spray for the sole purpose of producing a downward movement within the vessels of the plant. Gray (1919), however, in his early experiments found that the roots of the morning glory could be killed by spraying the plant with a sodium arsenite solution, though the method proved successful only at the coastbelt and under the most favourable conditions.

(d) *Arsenic pentoxide spray.*

As it appeared likely that arsenic pentoxide (owing to its hygroscopicity and corrosiveness) would be more effective

than the sodium arsenite used by Gray in his experiments, the effect of a 3 per cent. solution of this substance was tried out upon a branch of *Ipomaea purpurea*. The results are given in Table III (A) (see end). The initial effect of the arsenic pentoxide spray was to decrease the rate of water absorption, which continued to decline over a period of about ten hours, after which there was a slight increase. Although during the whole course of the experiment a backward flow did not occur, the very great decline in the rate of absorption suggested that under exceptionally favourable conditions a backward flow in the plant might be produced; this was apparently the case in some of Gray's experiments with sodium arsenite.

(e) *Chloroform.*

In Table III (B) are given the results of an experiment in which a branch of *Ipomaea purpurea* was placed in a closed atmosphere after chloroform had been poured over the leaves. It will be observed that a very rapid downward movement was produced. The rate of movement rose quickly—within 90 minutes—to a maximum, and then gradually declined. At its maximum it surpassed any other rate recorded during the whole course of this investigation. The very considerable downward movement of sap was doubtless correlated with the rapid and thorough killing of the leaves found to occur in this experiment. It is possible that the very rapid penetration of the chloroform into the leaves was due not only to the ability of its vapour to pass through the stomatic pores and across the intercellular air-spaces, but also, as Overton's solution theory of membrane action would suggest, to its solubility in the lipoids of the plasma membrane. It is also possible that the result of its action on the protoplasm was to set free more of the available water within the cells than was the case with the other chemicals used in this investigation.

(f) *Ammonium compounds.*

Greenham (1940) working on the skeleton weed found ammonium thiocyanate to be as efficient a penetrating agent as sulphuric acid. As it was thought that ammonium chloride, owing to the smaller size of its molecule, was likely to penetrate more readily than ammonium thiocyanate (previous field experiments had also pointed to the same conclusions), the effect of both these compounds was investigated. Ten per cent. solutions were applied to branches of *Ipomaea purpurea*; the results of these experiments are given in Table IV (see end).

It will be observed from the table that in the case of the branch sprayed with the ammonium chloride solution, all

movement of water either into or out of the branch ceased for some time. After this a very slight downward movement commenced and, having risen to a maximum, once more declined. In its general trend, therefore, a similar result to that given by sulphuric acid was obtained, although the actual amount of sap drawn back was considerably less.

The effect of the ammonium thiocyanate spray was not to produce a downward flow but to prevent or retard very considerably the rate of upward movement. The evidence obtained from this experiment therefore did not confirm the very good results Greenham obtained with ammonium thiocyanate as a penetrating agent.

(g) *Ring-barked stems.*

According to the theory of Crafts and Kennedy the downward movement occurring after the application of an acid-arsenical spray takes place through the xylem, and not through the phloem as has been suggested by Gray (1919) and Johnson (1928). Crafts and Kennedy (1930) have pointed out that such an active poison as arsenic would be almost certain to kill the cells of the phloem, the activity of which is necessary for translocation. Further evidence in support of the view of Crafts and Kennedy was obtained from an experiment in which the branches were first ring-barked and then sprayed with a 5 per cent. sulphuric acid solution. In each case the rings were cut on the portion of the stem projecting beyond the container, so that no suction was applied to the stem above the ring.

The results of this experiment are given in Table V (see end). It will be seen that the rate of downward movement rose to a maximum and then declined, no indication being given that the ring-barking of the stems in any way affected the downward flow of sap. It would therefore appear that the phloem is not the channel of movement, at any rate under the experimental conditions. This conclusion is supported by some early experiments in which it was found that if water was forced under pressure along a cut stem, no movement of either eosin or arsenic could take place against the current.

(h) *Scorching of the leaves.*

The problem as to whether scorching the leaves of a plant would produce a downward movement of sap appeared interesting from both the theoretical and practical points of view. A backward flow produced by scorching the leaves would indicate that the water supplied in the spray usually employed to kill the plant was not essential for the production of this movement. On the other hand, if it was found that

this backward flow was increased by spraying the leaves with water or an aqueous solution a practical application would suggest itself: scorching the leaves of deep-rooted perennial weeds followed by spraying with an aqueous solution of arsenic or other toxic substance might prove to be a practical method of eradication:

Two experiments were carried out to obtain information in connection with this problem. In both cases the leaves of a branch of *Ipomaea purpurea*, after it had been placed in the apparatus, were scorched with a blow-lamp. In the first experiment the branch received no further treatment, but in the second its leaves were kept damp by spraying them at intervals with water. The results of these experiments are given in Table VI (see end).

It was found that when the leaves were scorched, a downward movement soon commenced, i.e., within half-an-hour; but the rate of movement was extremely slow, and did not increase with time. In fact, a few hours later the dead branch was actually absorbing water, and the rate of this absorption continued to increase until the experiment was concluded.

In the second experiment it appeared that spraying the leaves with water enabled portions of some of the leaves to revive and regain their turgidity; these living patches, as soon as they were detected, were scorched and killed. The fact that an upward flow continued for some time after the commencement of the experiment was probably due to the absorption of water by those cells which remained alive. Therefore it would appear that a downward movement occurred only when all the leaves had been completely killed. Even then the rate of this movement was extremely slow. There appears, therefore, little likelihood of this method of producing a downward flow proving sufficiently effective to be of practical value in weed eradication.

(i) *Comparison of the readiness with which arsenic and copper were transported downwards in the sap.*

Crafts and Raynor (1940) have pointed out that, for translocation of a toxic substance to occur after spraying with a solution of a strong acid or base, it is necessary for the substance to be capable of moving through dead plant tissue. As field experiments had previously suggested that arsenic is usually much better translocated than copper, whatever the method used to effect penetration into the plant, it was decided to determine whether there was a difference in the ability of arsenic and copper to be moved downward by the mechanism under investigation. These previous field observations had suggested that copper is usually precipitated to some extent by constituents of the plant sap. The method

used in this investigation was to spray a branch of *Ipomoea purpurea* with a solution containing both arsenic and copper; sulphuric acid was also incorporated into the spray solution in order to produce rapid killing of the leaves and consequent downward movement of sap. The sap that was drawn back mixed with the water in which the cut end of the stem dipped, and was later analyzed for arsenic and copper. For determining arsenic the modified Gutzeit-Sanger-Meyer method as given by Vogel (1939) was employed. The copper was estimated gravimetrically after precipitation with salicylaldoxime, according to the method given by the B.D.H. Book of Organic Reagents for Delicate Analysis and "Spot" Tests (1937). These methods of analysis were first tested in the presence of plant sap and found to give consistent and accurate results.

In Table VII (see end) are given the results of four analyses of plant sap obtained by the method described above. It will be observed that in each case considerably more arsenic than copper was detected, despite the fact that in the spray solution the copper was in higher concentration than the arsenic. This indicates that arsenic is capable of moving more freely through dead plant tissue than copper, and hence suggests that the greater killing ability of the former is due not only to its higher toxicity, but also to the greater facility with which it is transported through the plant.

DISCUSSIONS AND CONCLUSIONS.

The main objection to the type of apparatus used in this investigation would appear to be that the use of cut branches was necessitated. As, however, it is generally accepted that a considerable tension normally exists within the vessels of an uncut plant exposed to dry conditions, the mere substitution of an artificial tension for one which may occur in nature would not appear to be a serious objection.

As has already been pointed out, some of the facts supporting the theory of Crafts and Kennedy can, however, also be satisfactorily explained on some other basis. For example, the greater effectiveness achieved by the incorporation of sulphuric acid in an acid-arsenical spray, might perhaps be due merely to the resulting increase in permeability of the leaves enabling better penetration of arsenic to occur, and not necessarily to the production of a downward flow. It is also to be expected that the hygroscopicity of the sulphuric acid, by hindering drying out of the spray on the leaves, would lead to increased penetration. Similarly, night-spraying or additional spraying with water after the application of the toxic solution, would, apart from the theory of Crafts and Kennedy, be expected to lead to more effective killing.

On the other hand, only the theory of Crafts and Kennedy appears to be capable of offering a satisfactory interpretation of their finding that, the drier the soil (other conditions being equal), the greater was the depth of killing; the suggestion that exposure to dry conditions weakens the plants and renders them more susceptible to poisoning would appear merely to avoid the difficulty. According to the theory of Crafts and Kennedy the greater depth of killing found to occur when the soil is dry, is to be accounted for by the high water deficit existing within the plant under these conditions. But in this connection it might be pointed out that Crafts and Kennedy (1930) have stated:

"Since eosin and arsenic solutions move unhindered through xylem tissues, if stems are cut under these solutions, the rate of uptake should be an index of the amount of water deficit existing in the plants at the time the stems are cut."

From the above statement, it would be concluded that, since water-deficit is an important factor in determining the depth to which killing is effected, an index to the results to be obtained by spraying the plants at a given time could be found by measuring the rate at which an eosin solution was absorbed by cut stems. But Morgan (1935), who investigated this problem, found that no correlation existed between the depth of killing and the rate of uptake of eosin solutions by cut stems.

It will be realized from the above facts that previously most of the evidence in favour of the theory of Crafts and Kennedy was of an indirect nature, and could not be considered conclusive. It is therefore hoped that the more direct evidence presented in this paper of the occurrence of a downward flow through the xylem will be of some value in support of this theory.

BIBLIOGRAPHY.

- BALL, W. S., CRAFTS, A. S., MADSON, B. A., AND ROBBINS, W. W.: Weed Control. California Agric. Expt. Sta. Ext. Circ. 97 (1936).
- B.D.H.: Book of Organic Reagents for Delicate Analysis and "Spot" Tests. London (1937).
- CRAFTS, A. S.: The use of arsenical compounds in the control of deep-rooted perennial weeds. *Hilgardia* 7: 361-372 (1933).
- CRAFTS, A. S.: Sulfuric acid as a penetrating agent in arsenical sprays for weed control. *Hilgardia* 8: 125-147 (1933).
- CRAFTS, A. S., AND KENNEDY, P. B.: The physiology of *Convolvulus arvensis* (morning-glory or bindweed) in relation to its control by chemical sprays. *Plant Physiol.* 5: 329-344 (1930).
- CRAFTS, A. S., AND RAYNOR, R. N.: Principles of chemical weed control. Herbage Publication Series: The control of weeds. Bull. 27: 38-54 (1940).
- CURTIS, O. F.: The translocation of solutes in plants. New York and London (1935).
- DIXON, H. H.: Transpiration and the ascent of sap in plants. London, 1914.

- GINSBERG, J. M.: Penetration of petroleum oils into plant tissue. *J. Agric. Res.* 43: 469-474 (1931).
- GRAY, G. P.: Spraying for the control of wild morning-glory within the fog belt. California Agric. Expt. Sta. Circ 168 (1917).
- GRAY, G. P.: Tests of chemical means for the control of weeds. *Univ. Calif. Publ. Agric. Sci.* 4: 67-97 (1919).
- GREENHAM, C. G., CURRIE, G. A., AND ALLAN, F. E.: Studies on chemical weed killers with special reference to skeleton weed. Commonwealth Australia Council for Science and Industrial Research Pamphlet 99 (1940).
- JOHNSON, E.: Recent developments in the use of herbicides in California. California State Dept. Agric. Mon. Bull. 17: 7-16 (1928).
- KENNEDY, P. B., AND CRAFTS, A. S.: The application of physiological methods to weed control. *Plant Physiol.* 2: 503-506 (1927).
- KNIGHT, H.: A micro-technique for observing oil penetration into citrus leaves after spraying. *Science* 68: 572 (1928).
- MORGAN, A.: The absorption and translocation of herbicides. *J. Dept. Agric. Victoria* 33: 200-208 (1935).
- VOGEL, A. I.: A text-book of quantitative inorganic analysis. Theory and practice. London, New York and Toronto (1939).
- YOUNG, P. A.: Distribution and effect of petroleum oils and kerosene in potato, cucumber, turnip, barley and onion. *J. Agric. Res.* 51: 925-934 (1935).

TABLE I.

Rate of water absorption of unsprayed branches of *Ipomoea purpurea* under experimental conditions

Time.	Rate of water absorption in ccs./gms. dry wt. of laminae/hr.		
	Expt. A.	Expt. B.	
11.00 a.m. — 12.00 noon	0.32	0.46	
12.00 noon --- 1.00 p.m.	0.36	0.54	
1.00 p.m. — 2.00 p.m.	0.43	0.58	
2.00 p.m. — 3.00 p.m.	0.43	0.52	
3.00 p.m. — 4.00 p.m.	0.43	0.46	
4.00 p.m. — 5.00 p.m.	0.43	0.46	
5.00 p.m. — 6.00 p.m.	0.53	0.49	
6.00 p.m. — 7.00 p.m.	0.36	0.31	
7.00 p.m. — 8.00 p.m.	0.32	0.28	
8.00 p.m. — 9.00 p.m.	0.28	0.28	
9.00 p.m. — 10.00 p.m.	0.28	0.31	
10.00 p.m. — 11.00 p.m.	0.28	0.31	
11.00 p.m. — 12.00 mdnt....	0.25	0.24	
12.00 mdnt— 1.00 a.m.	0.28	0.24	
1.00 a.m. — 2.00 a.m.	0.25	0.28	
2.00 a.m. — 3.00 a.m.	0.25	0.28	
3.00 a.m. — 4.00 a.m.	0.25	0.24	
4.00 a.m. — 5.00 a.m.	0.21	0.24	
5.00 a.m. — 6.00 a.m.	0.25	0.28	
6.00 a.m. — 7.00 a.m.	0.28	0.28	
7.00 a.m. — 8.00 a.m.	0.25	0.28	
8.00 a.m. — 9.00 a.m.	0.21	0.28	
9.00 a.m. — 10.00 a.m.	0.25	0.31	
10.00 a.m. — 11.00 a.m.	0.21	0.34	
11.00 a.m. — 12.00 noon	0.32	0.37	

TABLE II₄

The effect of, (A) a 5% sulphuric acid (by volume) and a 3% arsenic pentoxide (by weight) solution, (B) a 5% sulphuric acid solution, when applied as a spray to a branch of *Ipomaea purpurea*.

Time.	Rate at which water was absorbed by (—), or drawn back from (+), the branch in ccs./gms. dry wt. laminae/hr.	
	Expt. A.	Expt. B.
10.20 a.m. — 10.30 a.m.	—0.12	—0.23
10.30 a.m. — 11.0 a.m.	—0.10	0.00
11.00 a.m. — 11.30 a.m.	—0.04	0.00
11.30 a.m. — 12.00 noon	+0.09	+0.06
12.00 noon — 1.00 p.m.	+0.15	+0.12
1.00 p.m. — 2.00 p.m.	+0.17	+0.18
2.00 p.m. — 3.00 p.m.	+0.17	+0.19
3.00 p.m. — 4.00 p.m.	+0.17	+0.16
4.00 p.m. — 5.00 p.m.	+0.17	+0.15
5.00 p.m. — 6.00 p.m.	+0.12	+0.11
6.00 p.m. — 7.00 p.m.	+0.15	+0.11
7.00 p.m. — 8.00 p.m.	+0.13	+0.11
8.00 p.m. — 9.00 p.m.	+0.20	+0.11
9.00 p.m. — 10.00 p.m.	+0.15	+0.08

TABLE III.

The effect of (A) a 3% arsenic pentoxide solution applied as a spray, (B) chloroform, on a branch of *Ipomaea purpurea*.

Time.	Rate at which water was absorbed by (—), or drawn back from (+), the branch in ccs./gms. dry wt. laminae/hr.	
	Expt. A.	Expt. B.
11.20 a.m. — 11.35 a.m.	—0.32	—
11.35 a.m. — 11.50 a.m.	—0.27	+0.07
11.50 a.m. — 12.00 noon	—0.20	+0.30
12.00 noon — 1.00 p.m.	—0.19	+0.52
1.00 p.m. — 2.00 p.m.	—0.20	+0.40
2.00 p.m. — 3.00 p.m.	—0.11	+0.32
3.00 p.m. — 4.00 p.m.	—0.08	+0.32
4.00 p.m. — 5.00 p.m.	—0.07	+0.27
5.00 p.m. — 6.00 p.m.	—0.06	
6.00 p.m. — 7.00 p.m.	—0.11	
7.00 p.m. — 8.00 p.m.	—0.05	
8.00 p.m. — 9.00 p.m.	—0.03	+0.18
9.00 p.m. — 10.00 p.m.	—0.05	+0.15
10.00 p.m. — 9.00 a.m.	—0.07	—
9.00 a.m. — 10.00 a.m.	—0.07	—

TABLE IV.

The effect of a 10% solution of (A) ammonium chloride, (B) ammonium biocyanate, when applied as a spray to a branch of *Ipomoea purpurea*.

Time.	Rate at which water was absorbed by (—), or drawn back from (+), the branch in ccs./gms. dry wt. laminae/hr.	
	Expt. A.	Expt. B.
9.55 a.m. — 10.15 a.m.	0.00	—
10.15 a.m. — 10.30 a.m.	0.00	0.00
10.30 a.m. — 11.00 a.m.	0.00	-0.03
11.00 a.m. — 12.00 noon	+0.02	-0.02
12.00 noon — 1.00 p.m.	+0.04	0.00
1.00 p.m. — 2.00 p.m.	+0.06	-0.01
2.00 p.m. — 3.00 p.m.	+0.05	0.00
3.00 p.m. — 4.00 p.m.	+0.05	-0.01
4.00 p.m. — 5.00 p.m.	+0.04	-0.01
5.00 p.m. — 9.30 a.m.	0.00	-0.01

TABLE V.

The effect of a 5% sulphuric acid spray on branches of *Ipomoea purpurea*, the stems of which had been ring-barked.

Time.	Rate at which sap was drawn back from the branches in ccs./gms. dry wt. laminae/hr.	
	Expt. A.	Expt. B.
10.00 a.m. — 11.00 a.m.	+0.09	—
10.20 a.m. — 11.00 a.m.	—	+0.00
11.00 a.m. — 12.00 noon	+0.27	+0.21
12.00 noon — 1.00 p.m.	+0.35	+0.23
1.00 p.m. — 2.00 p.m.	+0.27	+0.23
2.00 p.m. — 3.00 p.m.	+0.21	+0.19
3.00 p.m. — 4.00 p.m.	+0.06	+0.08
4.00 p.m. — 6.00 p.m.	+0.06	+0.04

TABLE VI.

The effect of (A) scorching the leaves, (B) scorching the leaves and spraying with water, on a branch of *Ipomoea purpurea*.

			Rate at which water was absorbed by (—), or drawn back from (+), the branch in ccs./gms. dry wt. laminae/hr.	
			Expt. A.	Expt. B.
10.00 a.m.	—	10.30 a.m.	... ... +0.08	—0.02
10.30 a.m.	—	11.00 a.m.	... ... +0.08	—0.04
11.00 a.m.	—	12.00 noon	... ... +0.02	—0.05
12.00 noon	—	1.00 p.m.	... ... —0.03	—0.03
1.00 p.m.	—	2.00 p.m.	... ... —0.08	—0.01
2.00 p.m.	—	3.00 p.m.	... ... —0.10	+0.01
3.00 p.m.	—	4.00 p.m.	... ... —0.13	+0.03
4.00 p.m.	—	5.00 p.m.	... ... —0.14	+0.02

TABLE VII.

Analyses of sap drawn back from the leaves after they had been sprayed with a solution containing 5% sulphuric acid by volume and 3.33% arsenic pentoxide and 4.55% copper sulphate by weight.

No. of Expt.	Duration of Expt. in hrs.	Amount of sap drawn back in ccs.	Gms. copper (calcu- lated as CuSO_4) in sap drawn back.	Gms. arsenic (cal- culated as As_2O_5) in sap drawn back.
1	25 $\frac{1}{2}$	17.6	.0016	.0139
2	25 $\frac{1}{2}$	5.7	.0009	.0062
3	24	4.8	.0015	.0056
4	24	4.35	.0007	.0061

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SOME OBSERVATIONS ON THE RELATIONSHIP BETWEEN VEGETATION AND INSECT POPULATIONS

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Read 29th June, 1942.

I. INTRODUCTION.

The bio-ecological concepts discussed below have emerged from a study of insect behaviour. Since 1938 several communities—both climax and successional stages—in the Highveld of the Transvaal have been periodically examined to determine the daily, seasonal and cyclic fluctuations in the numerical abundance of selected insect species. The effect of these population fluctuations on quantitative estimates of the reaction caused by an insect necessitates the application of a "rate x time" concept, where the first multiplicand reflects the size of the population and the second multiplicand expresses the time spent by an insect in any one of its ecological forms (causing any one type of reaction).

Attention has been paid to the principles of insect succession as compared with plant succession, and a revised interpretation of community functions is suggested for use in bio-ecology.

It is clear that a better understanding of the principles of insect community ecology will be of practical use in the field of economic entomology.

II. METHOD OF STUDY.

It is not satisfactory to state the size of an insect population without mentioning the number of host-plants in the area. A statement of the number of individuals per plant or per flower-head is a complete analysis of the incidence. About 50 to 100 plants are examined and the number of insects noted. Alternatively, the average number of individuals per plant is roughly estimated.

The method of estimating the exact size of an insect population, as described by Jackson (1939) in his study of the tsetse fly, would be in my work an incomplete analysis

of incidence, unless the number of hosts in the area were known. When one is working in small stands, traps have the disadvantage of attracting insects from adjacent communities, and in the case of light traps the size of the area sampled depends on the prevailing visibility.

III. REACTIONS CAUSED BY INSECTS.

Instead of utilising a concept of the reactions caused by each insect species as a whole—the total of the different reactions resulting from the various activities of which an adult and its larva are capable,—a concept of an “ecological form” has been substituted. Such an ecological form is capable of one activity only, be it the feeding of an adult or the resting of the same adult, because by definition an ecological form is a certain metamorphic stage engaged in any *one* of its activities. It is felt that even a single metamorphic stage is too clumsy as a concept of a *community member*, since an insect often rests in a different community from the one in which it feeds, and it may lay its eggs in yet another community. Nor is there an abrupt change-over from one activity to another; in a population of the beetle *Astylus atromaculatus* Bl., for example, as much as three-quarters of the population has been found inactive while the other quarter was feeding, when the weather is cloudy or when caged beetles were put in the shade at 2.30 p.m. on a hot day. The periods of prevalence of the ecological forms, therefore, overlap. For these reasons I suggest the concept of a *community member*. For each ecological form we can estimate the period of prevalence and the fluctuations in the population, both of which are controlled not only by a change-over from a feeding to a resting form, but also by a change from one host species to another in the case of insects which have more than one host-plant. An ecological form, say a larval Lepidopteron feeding, can change its food and its community and it is still the same form, as long as it is still a larva and is feeding. The ecological form includes all the individuals in that stage and activity. The separation of the ecological forms alternately assumed by any particular insect species depends on the recognition of an adult as three separate forms when feeding, resting and egg-laying, and similarly the recognition of a larva as a feeding form and a resting form. An insect species therefore loses its entity, and may become a maximum of five ecological forms, perhaps each one a different ecological type. The effects on any one form of the demands and tolerances of the other forms with which this form alternates in accordance with changing activity during the day and season are interpreted by including as the demands of the one form the necessity for

a community suitable to the others within reach of this form's community.

The point of view adopted in judging the rôle played by an insect is its effect on the rate and nature of succession in the community. As regards insects feeding on plant-parts, it is practicable to judge the reaction from the standpoint of the well-being of the host. This judgment on a basis of plants applies also to parasites of animals, since all animals are ultimately dependent on plants for their food. The larvae of the moth *Orneodes tesserata* Meyr. (Copromorphinae, Tineidae), which cause terminal-bud galls on the shrub *Pavetta* sp., are regarded as a "harmful form." The hymenopterous parasite that was found heavily infesting the larva is classed as a "helpful form" because it benefits the *Pavetta*. Many types of insect activity, such as the feeding of adult fruit-flies, are quite incidental. Helpful forms are those that tend to increase the host-plant, and in so doing increase the rate of plant succession. Soil improvement by coleopterous larvae is regarded as a helpful activity. Harmful forms are those that tend to decrease the rate of plant succession by adversely affecting the growth-rate, the size and the output of seed of the host-plant concerned, and consequently lessening the effect of the plant on its environment. In the Transvaal Highveld, Man with his fires and cattle is a harmful ecological form, because as a result of burning and grazing the vegetation is kept in a sub-climax grassland stage of succession. In one subdivision of the Highveld the vegetation in this biotic community is a *Trachypogon*—Other spp. veld, in the other an equally stable *Themeda triandra* veld, a grassland in which *Trachypogon plumosus*, *Tristachya hispida* and *Elyonurus argenteus* have been replaced by *Themeda* which is a lower successional stage. Both helpful forms and harmful forms, of course, affect the nature of plant succession, since they are part of the character of each of the plant species.

For the sake of comparative standardisation, it is advisable to grade ecological types of activity according to the part of the plant affected. A stem-gall, although not causing abortion of the shoot, is usually regarded as harmful to the host-plant, but its importance pales when compared with the effects of a terminal-bud gall prohibiting any further development of the shoot into branches. *Stoebe vulgaris* is a noxious weed in grasslands, and it is almost invariably heavily infested by a bud-gall (Cecidomyidae). It is not unlikely that the increase of the bushes is controlled in part by the gall-insect, and it is therefore unfortunate that a biotic equilibrium has been established and that the dipterous larva is often heavily parasitised by a Hymenopteron.

DISTRIBUTION IN TIME OF PREVALENCE.

In my opinion, the difficulty in describing clearly and concisely the animals in any community is that animals are characterised by their coming and going during the day and season. The various species of one community disperse amongst several different communities, and if one is to get a picture of the former, one must not be distracted by the behaviour of the animals in the other communities. Since a species is not present all the time, one must know how much time is spent in each community. Hence the concept of the daily, seasonal and cyclic distribution in time of prevalence, that is the time factor in reactions. In my work on insects, I regard an ecological form as a community member and describe the distribution in time of each form separately.

The time factor in reactions deals only with the presence or absence of an ecological form, and does not consider the size of the population. The importance of the time spent in any activity becomes evident when one realises what big variations there can be from one day to the next in the length of the daily period of activity of a nocturnal or diurnal insect. Adult Spotted Maize Beetles, an agricultural pest (*Astylus atromaculatus* Bl., Melyridae), have been kept under observation on maize and numerous other plants such as *Paspalum dilatatum* and *Cyperus esculentus*. The prevalence of the feeding form seems to depend on solar radiation. In the morning they become active when the sun's rays strike them and before the air temperature has increased, especially individuals in exposed sleeping-places. In the evening they become inactive before sunset. On wet cloudy days they remain comparatively inactive.

Seasonal distribution of prevalence further limits the time spent by an insect in any one activity. I refer to prevalence in a particular community (successional stage) rather than just anywhere in the district. Climatic factors and the presence on the host in the right condition of fruit, flower, etc., control hibernation and migration. But in species that have alternative hosts the number of days spent in each community is still further reduced by counterattraction. This latter hypothesis must be the explanation of the fact that *Astylus* was common at Frankenwald Botanical Research Station throughout the 1940-41 season, from mid-January onwards, and yet the beetles did not feed on maize until sometime in February. Maize-lands a few hundred yards away were in tassel and young-cob stage at the time. Maize in which no *Astylus* could be found early in March 1941 was in the right state of development. Even in the 1939-40 season, when much damage was done to maize by

this beetle, it fed on maize for a few weeks only, although once again maize was present and beetles were common on the farm. Between the 18th and 28th February 1940, *Astylus* in one mealie-land was feeding on the spores of a fungus on the weed *Portulaca oleracea* and ignoring maize, although the maize was shedding pollen in profusion. It is instructive to realise that this beetle—which is numerically abundant each season, but fortunately feeds most of the time on veld grasses and composites—is prevented from becoming a serious pest possibly *only because of the small difference in relative attraction and the time of flowering of its alternative host-plants*, i.e. because of the delicate balance of counter-attraction.

Cyclic distribution of prevalence in any particular community is conceivably due to two phenomena. A small brown beetle (Chrysomelidae) was found to be very common on *Cymbopogon plurinodis*, feeding on the young spikelets, during January 1939, but has not been seen in the district since. Another beetle, *Macrocoma aureovillosa* Marsh. (Eumolpinae, Chrysomelidae), was feeding on *Trachypogon plumosus* and *Cymbopogon* in January 1939, removing the anthers from unopened spikelets. During the two following seasons this species could not be found on these plants, even though the community is a relatively stable subclimax one and the beetle was present in the vicinity. Apparently this behaviour is due to the relative time of flowering of alternative hosts and counter-attraction.

POPULATION FLUCTUATIONS.

The rate factor, which completes my concept of a reaction, serves to reflect the size of a population during the period of its prevalence in any one community. I am measuring populations in particular micro-habitats rather than the number of individuals in the district.

Seasonal fluctuation seems to be from a small percentage infection to a peak near the end of the period of prevalence, due to breeding in the case of insects with a short life-cycle, and in other cases due to seasonal migrations or to a change in the size of the host population (the insect population remaining steady) since I am using a percentage measurement of infection. During spring and summer, when food is abundant, *Astylus atramaculatus* only very occasionally feeds on cultivated garden plants, but on 6th May 1940, after the first frosts, this species was very common to abundant on the flowers of chrysanthemums on a farm near Leslie, a bleak part of the Highveld. This peak of infection is presumably correlated with the growing scarcity of host-plants

as winter approaches, rather than with any increase in the number of beetles on the farm. Seasonal population fluctuations, in other words, are a result of the effects of weather conditions on the larva, the pupa, the adult or the host-species. Predators and other parasites are in some instances of major importance in controlling a population as, for example, in the case of the Armyworm (*Laphygma exempta* Walk.), the second generation of which is invariably decimated by several parasitic species.

Daily fluctuations in the size of an insect population during the period of prevalence of the species as a feeding or an egg-laying ecological form have been studied by many workers in recent times. Cyclic fluctuations, those from one season to another, are also important in quantitative estimates of the ecological rôle of any type of activity of an insect.

In using the "rate x time" concept, one has either to arrive at an average rate (size of population) or to use a mode of expression similar to that of "cattle-days" used in grazing experiments with cattle. Including the size of a population is akin to adding the second side of a rectangle: whatever terms we use, the ultimate quantity is two-dimensional. It is suggested that the practice of dividing a species into several forms according to the number of types of activity of which the species is capable, and regarding each form as a separate community member will be equally useful in the study of animals other than insects. For each form (ecological type of activity) one describes the period of prevalence in each community and the fluctuation of the population in each of the communities.

IV. INSECT SUCCESSION.

Although it is at once obvious that some animal species do compete with one another for existence in a community, this seems to be the exception rather than the rule. Certain of the larger species of game are known to frighten the more timid species of buck away from pastures, and zebra and wildebeest eat off all available grazing in some areas. Man is forever competing with the pests on his farm for the same crops. But, although different individuals of *one and the same animal species* compete with one another, *different animal species* usually do not have equivalent food demands and so fewer species visit any particular host species. Insects are so often specific in their choice of host-plants that there are in my experience seldom more than a few species on any one kind of plant, and of these some may feed on pollen and others on seeds. Forest insects are, of course, notable exceptions, and many hundreds of species occur on some trees such as the oak. Parasites of animals are very often specific in their choice of a host.

As one community follows another in the process of succession, one set of insect species follows the next, but not because one set competes with another, rather because the plants with which the ousted insects are associated have been ousted. *It is therefore incorrect to regard competition as the mechanism of insect succession.* The same applies to other animals, since all animals are ultimately dependent on plants, and their sphere of interest is limited by their hosts. Green plants have not this limit, because they synthesise their food from the universal constituents of air and soil. Their food demands are the same, though of course each species collaborates with any particular habitat to a different degree peculiar to the species. All plants the seed of which is available compete with one another for a place in the community.

Both plant and animal ecologists could use a concept of degrees of collaboration with the habitat, instead of the accepted concept of competition. In succession an invading plant collaborates with the habitat at the expense of the preceding community. An animal belonging to the higher successional stage collaborates with the habitat not so much at the expense of the preceding animals, but rather because the plants supporting the ousted animals have given way to other species of plants. "Collaboration with habitat" + "at the expense of" = the concept of competition, elaborated more particularly by Clements (1904, 1905) and by Clements, Weaver and Hanson (1929) as the mechanism of plant succession, and used to-day in plant ecology.

CONCLUSION.

Although the concepts put forward above are unnecessarily elaborate for plants, it is felt that in bio-ecology there should be a single set of concepts and a single terminology. As Phillips (1931) points out, plants and animals in their environment cannot be separated.

ACKNOWLEDGMENTS.

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REFERENCES.

- CARPENTER, J. R.: Quantitative community studies of land animals. *J. Anim. Ecol.*, 5: 231-245 (1936).
- CLEMENTS, F. E.: Development and structure of vegetation. *Rep. Bot. Surv. Nebr.*, 7: 5-175 (1904). Cited by Clements and others (1929).
- CLEMENTS, F. E.: Research methods in ecology (1905). Cited by Clements and others (1929).
- CLEMENTS, F. E., AND SHELFORD, V. E.: Bio-ecology. Wiley, New York (1939).
- CLEMENTS, F. E., WEAVER, J. E., AND HANSON, H. C.: Plant competition; an analysis of community functions. Carnegie Inst. Wash. Pub., 398 (1929).
- JACKSON, O. H. N.: The analysis of an animal population. *J. Anim. Ecol.*, 9: 328-335 (1939).
- PHILLIPS, J. F. V.: The biotic community. *Ecology*, 19: 1-24 (1931).

MECHANICAL ADJUSTMENT OF STEM PROFILE

BY

JOHN M. TURNBULL,

*Forest Products Institute, Pretoria.**Read 29th June, 1942.*A CONSIDERATION OF THE LAW OF THE VERTICAL
SUCCESSION OF TEETH

BY

F. G. CAWSTON, *Durban.**Read 29th June, 1942.*

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AGAR FROM SOUTH AFRICAN SEAWEEDS

BY

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Read 29th June, 1942.

ABSTRACT.

Agar is a substance obtained from certain kinds of seaweeds and is valued because it possesses the property of forming strong gels in very low concentrations. Its many uses in industry, medicine and particularly in the making of bacteriological media have been briefly reviewed in a recent paper by Isaac (1942).

Its chief constituent is a pectin-like substance d-galactan, or gelose as it is usually called; this is present in purified agar to the extent of about 23-25 per cent. It was formerly obtained mainly from Japan and to a lesser extent from China and the U.S.A., but, since the outbreak of war, these sources of supply have been cut off and several countries including Australia, New Zealand and Great Britain have been compelled to develop their own supplies of a product which is of vital importance.

In response to several requests we have made a brief study of the varieties of seaweed that could be obtained locally for agar production; we have also studied the methods of extraction, the yields obtainable and the way in which the crude product can be refined and dried.

It is satisfactory to be able to state, as a result of these investigations, that suitable varieties of agar-containing seaweeds are obtainable locally; that some at least of these occur abundantly, or at least in sufficient quantity to make their collection practicable; and that the process of manufacture presents no real difficulties. Already purified but undried agar is being used commercially and there is every reason to believe that before long supplies of the high quality product needed by the bacteriologist will be available.

Before the war about sixteen species of Red Seaweeds were regarded as suitable sources. Of these, two almost

cosmopolitan forms *Gracilaria confervoides* and *Gelidium cartilagineum* are found on the South African coast; there is also some evidence that *Gelidium corneum* may occur in smaller amounts on the coast of the Eastern Province.

Four other South African seaweeds have now been proved by investigation to be suitable for the purpose, namely *Gelidium pristoides*, *Hypnea spicifera*, both of which are endemic to our coasts; *Suhria vittata*, a South Atlantic seaweed, and *Caulocanthus ustulatus* of the African and Mediterranean coasts.

The following summary gives a brief survey of the distribution of these six seaweeds round the coast of the Union, with their general habitat and relative abundance. The "common names" in brackets are improvisations to assist non-botanical collectors.

1. *Gracilaria confervoides* ("Sea String"). This grows below lowest tide level on the cold Atlantic side of the Union, but only where it can have sheltered water and a firm sandy or sand-and-rock bottom—a combination very rare on the exposed west coast. Submerged meadows of it occur in the fishing cove at Hout Bay and the lagoon at Langebaan, from which large quantities are cast up on the beach by the ground-swell of winter storms. It there resembles a tangled mass of dark red string, fading through pink to yellow.

It is this seaweed which is proving of immediate practicable value as a source of agar for commercial purposes.

2. *Gelidium cartilagineum* ("Red Lace") grows in bunches which hang from the rocks between ordinary and spring low-tide marks, like jabots of crimson-red lace. It grows right round our coasts, both on the cold and warm sides and is especially abundant in False Bay.

This weed proved disappointing at first, but was found to contain large amounts of agar when improved methods of extraction were tried.

3. *Gelidium pristoides* ("Brown Sea Parsley") is common and abundant from False Bay eastwards to Cape Morgan. It looks like bunches of fine curly reddish-brown parsley, growing from the mid-tide mark to below low tide.

It is an excellent source of agar, which can very readily be extracted.

4. *Hypnea spicifera* ("Green Tips") bears slender tufts of glossy spikes, reddish brown in general colouring but very often with its upper portions a curious violet-green shade. It grows abundantly from False Bay eastward to Natal,

increasing in size with the warmer water from about an average of five inches in False Bay to over two feet on the eastern coast. Occasional stunted specimens are to be found on the Atlantic coast.

5. *Suhria vittata* ("Red Ribbons") was used for jelly making by the early settlers, and is still preferred to gelatine by some housewives. It looks like a bunch of narrow red ribbons, each with a very delicate fringe along both edges, growing below low-tide level. It is most often found on the stems of *Ecklonia buccinalis*, a big kelp commonly known as "Sea Bamboo," though it also grows on shells and rocks. These two seaweeds are typically cold-water and grow along the Atlantic coast, but are also found on exposed parts of the south coast as far as Cape Agulhas.

It is an excellent source of agar, which can be very easily extracted.

6. *Caulacanthus ustulatus* consists of short branching brownish threads which grow about mid-tide level in any slight rock-hollow where a little sand has accumulated. The general effect is of a worn doormat across which sand has drifted. It is very common, but too small to be of practical value as a source of agar when compared with the five larger seaweeds.

Several other seaweeds have been tested and shown to contain considerable quantities of agar.

As would be expected several practical difficulties were encountered when studying the methods of extraction and purification. The advantage of previous sun-bleaching is stressed, as it obviates the necessity of decolourising the extract. Heating under pressure greatly improves the yield, particularly with some seaweeds. Yields are extremely good and often amount to fifty per cent. or more calculated on the air-dried weight of seaweed. Drying is best accomplished by freezing and thawing, which destroys the gel structure and allows the water to escape. The products obtained were subjected to bacteriological tests which proved to be very promising.

If the manufacturing process can be placed on an economic basis there seems no reason why local production should not in future entirely replace the imported product.

AGRICULTURE AND SCIENCE

BY

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of the Witwatersrand.*

Read 30th June, 1942.

ABSTRACT.

One of the principal objects of this paper has been to trace the influence of scientific thought and of the individual sciences on the development of agriculture, and to establish that this influence has been profound and decisive throughout the ages—though different in different epochs—and continuous in spite of temporary interruptions.

Bearing in mind the historical fact that science itself has been developing, and the natural fact that agriculture could at most advance at an equal pace with general science or the sciences upon which it has to draw, we gain some insight into the manifold development of agricultural science and agriculture, with its ebbs and flows, departures from the various modes of thought and action and reverersions to them—witnessing also the general development of civilization in the face of agriculture—until we find the strongest influence and closest interconnexion of agriculture and science in the period coinciding more or less with the Industrial Revolution.

Science has contributed to agriculture in various ways, and mainly through the agricultural sciences proper and the applications of the positive and social sciences to the field of agriculture. But what has shaped and moulded agriculture has been scientific thought as such and the resulting attitude of mind.

The agricultural sciences proper, though differing notably from each other and being each connected with other sciences outside agriculture (Plant Husbandry with Botany and Animal Husbandry with Zoology) present many outstanding similarities which group them together in one more or less homogeneous whole clearly distinguished from the other groups of sciences. This group differs very markedly from the group of positive and social sciences applied to agriculture, and still more so from that of the pure sciences

from which these last proceed. The distinction between the three groups should be heavily stressed, in view of the great differences among them in aims, subject-matter, methods and means. These differences vary as between the different groups and as between the individual sciences in the groups. They also vary as regards the various items, the differences in subject-matter and in methods being fundamental in every case.

It is especially noteworthy that the dominating factor in agricultural methods is their synthetic character, the elements being taken mostly ready-made from the other sciences (Botany, Zoology, etc.) as well as from the agricultural sciences themselves. A holistic attitude is therefore most essential in facing the multiform agricultural problems. In this way, agricultural science possesses a certain indisputable advantage over a number of other sciences both as an organic entity and as a cultural means.

Now, in considering the contribution of agriculture to science and civilization, we may sum up its achievements as follows:

A fuller understanding of nature's ways has enabled us to control her elements, utilize her benefits to advantage, overcome her recalcitrances and even improve upon her activities, with the result that we have obtained increased production, better and more economical producing conditions and finer products. Thus agriculture has largely contributed to man's comfort and to the satisfaction of his material wants.

Yet, in addition, agriculture has helped man in his intellectual activities. By virtue of its very nature and the character of the research involved, it has contributed to the promotion of science and the scientific way of thinking. Furthermore, the recognition of the contribution of agricultural, related and auxiliary sciences to the promotion of economy and welfare, has been a strong stimulant to the expansion and intensification of science and to the increase of the material means at its disposal.

Although it is impossible to foresee what progress agricultural and related sciences and agriculture will make in the future, yet it can be affirmed without hesitation that the achievements will be overwhelming if agricultural research only receives the requisite attention and the appropriate direction.

NOTE: Prof. Boyazoglu's paper on "Agriculture and Science" is being published by the University of the Witwatersrand.

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ON THE POSSIBILITY OF USING SODIUM SELENITE FOR SEED TESTING OF KAROO BUSHES

BY

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Read 30th June, 1942.

In the past few years I have several times spoken on the germination of seeds of Karoo bushes. The data given were based on the usual germination tests. From the practical point of view the most important finding was that a large number of Karoo bushes do not germinate at all just after their harvest but have a long time of after-ripening. In extreme cases one has to wait for a year or more to know whether the collected seeds are viable. Owing to late rains and early frosts the harvesting of these seeds often falls when there is frost at night. As the collecting is a slow and tedious job, it would be of great value to know at once whether the seeds collected are viable or not, and an immediate test was looked for, although it was known that a particular seed would only be good for sowing in a year's time.

My attention was drawn by Mr. C. Liebenberg to an article by Eidman (1938) on testing seeds with acid sodium selenite at a pH of 4·5, claiming that this reagent imparted a red colour to the seeds varying in accordance with their degree of viability. No special apparatus was required, light and temperature was immaterial and the whole test was completed within 72 hours. Few chemical details were however given, e.g., it was not mentioned how the necessary pH was obtained, nor was acid sodium selenite procurable at the time. A small quantity of Selenious acid was obtained and Dr. Copeman advised on the preparation of the sodium salt.

It proved better however to prepare a 2% solution of the acid and buffer with one of Clarke's buffers containing NaOH. Phthalate—NaOH mixtures (50 c.c. n/5 KH—Phthalate + 29·75 c.c. n/5 NaOH dilute to 200 c.c.), or citric acid—NaOH + HCl (21·008 gr. citric acid + 200 c.c. n NaOH per litre HCl: 0·1n) citrate 8 c.c., HCl 2 c.c., proved most useful for the purpose. To the small quantity of Sodium selenite the buffer recommended by Morrow 0·0005 nHCl was

used; Brom cresol phenol was used as an indicator. In many preliminary tests the citric acid buffer proved the best; as white coated seeds showed red colouring within a few hours soaking in the solution.

The main difficulty lies in a different direction. Many Karoo bush seeds are not white-coated, but black, and the seed coat may be extremely thick so as to be almost impenetrable to the acid. Eidman advises the removal of the outer seed coat, but this is somewhat difficult with seeds of the Compositae and other tiny seeds common in Karoo bushes. It must be admitted that even with black-coated seeds as some harvests of *Walafrida geniculata* are, a red tinge can be seen, and after the seeds have been in the selenite solution for 48 hours, the seed coat can be more easily removed and the red colour more readily seen.

The most suitable method for seed testing with sodium selenite appears to be as follows: Count out the seeds and empty fruits, or seed coats as the case may be. Empty seed coats should be deducted as "not germinating" in the percentage of germination. The seeds are put into water for 24 hours which often provokes germination at the end of the season if the temperature is not too low. These seeds are counted as "germinated." They immediately turn red in contact with selenious acid. Before placing the seeds in the acid it is advisable to dry them slightly with blotting paper in order not to dilute the acid. The seeds are examined at intervals during 48 hours. Within the first few hours a number of seeds reduce the acid to red selenium which they store. Seeds which after 48 hours are only spotted red, not completely red (German "Mattkeimer") may germinate (especially in an artificial experiment) but will never give a healthy plant, as only healthy tissue can reduce the selenious acid.

A number of tests were made and quite good results were obtained, but for the time being it is not thought that the method could make the usual germination test superfluous. In a few cases, for instance with *klappiesbrak*, the reduced Selenium looked rather brownish not pink or red, and yet it was known from practical experience that the seeds were excellent. On the other hand for seeds which show delayed germination the method can certainly be used to advantage. The following small table may illustrate this point. *Tetragonia* freshly harvested shows potential germination to a very marked degree with selenite, whilst no germination is recorded in the incubator; older seeds show with both methods about the same percentual germination. *Atriplex* sp. and *Tripteris pachyptera* show a similar discrepancy for

fresh seeds. *Walafrida* sp. which usually germinates after 2 years of after-ripening, indicates its vitality with the selenite tests. *Pentzia incana* 1940 and *Panicum Makarikariensis* 1942 show their non-vitality with both methods, they were old enough to be sown.

It is obvious that the method will give some useful information, but it will never do away with the usual germination test. The latter will always be used to determine the length of after-ripening, and the influence of any other factor.

Plant	Phtha-late-Selenite	Citrate-Selenite	Sodium-Selenite 0.00005n H.C.L.	Incuba-tor test	Remarks
<i>Tetragonia arboscule</i> 1940 ...	—	96	96	95	Tested without hulls, 15 months old.
	—	—	98	0	In hulls.
	—	—	89	85	After 2 yrs. tested without hulls.
<i>Do.</i> 1939...					
<i>Do.</i> 1941...	10 not really pink	60 but about half only spotted	30	0	Tested three months after harvest without hulls.
<i>Atriplex</i> <i>Mulleri</i> 1940	—	90	90	11	Without seed coats
<i>Atriplex</i> <i>capensis</i> 1941	—	76 9 partly red	87 6 partly red	43	Outer seed coat removed.
	—	21 5 partly red	23 12 partly red	21	In seed coat.
<i>Pentzia</i> <i>Incana</i> 1940 ...	—	2	2	3	—
<i>Triptoris</i> <i>pachypleura</i> 1939 ...	—	75	76	56	—
<i>Walafrida</i> <i>geniculata</i> 1940	—	97	—	0	Tested in 1942.
<i>Panicum</i> <i>makarikarien-sis</i> 1942 ...	—	0	—	0	—
<i>Do.</i> 1941	—	21	21	21	Tested in 1941.

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TRANSPERSION OF GRASSES IN THE SOUR
MOUNTAIN GRASSVELD OF THE DRAKENS-
BERG IN COMPARISON WITH THE WATER
LOSS OF INDIGENOUS FORESTS.

BY

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When the problem of the water catchment areas was discussed, opinions were heard that it might be better to have water catchments under grass and not under forests at all. It was thought that the water consumption of the grass veld would be smaller than that of the forest. At that time no data on the transpiration of either formation were available. Some years ago an investigation on the transpiration of the indigenous forest trees in the Drakensberg was made and the values obtained recalculated to units of soil. This work was done at Cathkin Park. As this area also contains sour mountain grass veld, the present investigations carried out in November, 1941, and March, 1942, were also made there. Other areas within a radius of 60 miles in the Drakensberg area were visited, for instance Tabamhlope. Cathedral Peak area, the surroundings of the Natal National Park and the area of Champagne Castle. It was found that in all these areas the same veld burning at the end of the winter was practised, and in quite a number of places a second burning took place at the end of summer. It is not the purpose of this paper to go into the veld management of these areas, but it must be emphasised that the veld which was investigated was disturbed veld. The present condition and the present vegetation are considered characteristic for the whole area and under the present grazing system would scarcely be altered.

The actual work was done on the former golf course of Cathkin Park and the adjoining farm, the grass veld being surrounded on the East by wattle plantations, on the West by the 'Ndema forest. It is fairly level except on one side where there is a gentle slope to the hydrosere of one of the small mountain spruits. The golf course itself is burnt, but the clearances in the plantation are little affected by the fire. The vernal aspect is very different from the autumnal aspect,

but the paucity of haulms is characteristic of both seasons on the burnt area; so few were the spikes that for a long time the different species could not be identified and had to be worked with numbers. *Alleteropsis semi-alata* var. *Ecklonii* was dominant in springtime. Leaves of *Trachypogon plumosus* were only found in places more protected from the winter fire. *Themeda triandra*, *Eragrostis chalcantha*, *Digitaria tricholaenoides*, *Panicum Ecklonii*, a small *Andropogon*, roll leaf, *Elionurus argenteus* and *Rendln Nelsonii* were just beginning to grow in the midst of many bulb plants and Leguminosae. *Tristachya hispida* and *Harpechloa Falz* only appeared in the later part of the Spring investigation. The hydrosere especially was very late. Midst of November leaves of *Cymbopogon validus* and *Misanthidium* were only a foot high.

In the autumnal aspect *Trachypogon plumosus* was dominant and one of a few species having haulms and spikes. On the golf course itself *Paspalum dilatatum* was conspicuous, *Eragrostis chalcantha* much less so than in spring. *Monocymbium cerisiiforme* appeared to a large extent. *Tristachya* was still present; but *Harpechloa*, *Digitaria* and *Panicum* were difficult to find. The roll leaves were hidden under the masses of other grasses. Very few non-Gramineae were present.

In the hydrosere the *Cymbopogon* and *Misanthidium* with spikes were over man's height, but small grasses were found between.

The method used was the same as in previous experiments. On the transpiration torsion balance of Hartmann and Braun readings with the different grass leaves at intervals of 3 minutes were taken, the results calculated on fresh matter and surface. From former investigations with grasses done in South Africa it was expected that a large transpiration power would be recorded.

With regard to the weather in which the experiments were made, the October-November period was decidedly dry, getting drier towards the end of November. The March period was very wet; of course drought conditions are relative to the district, and a drought in the Drakensberg is a very different thing from a drought in the Karroo: but as the plants in a high rainfall area are not accustomed to drought, they are hit as hard as or harder than real xerophyllous plants. Compared with the seasons 1937 and 1938 when the trees in the Drakensberg were investigated, the season 1941/42 had never as high temperatures as those recorded near the 'Ndema forest or the Eucalyptus plantations, but the air was much more saturated in 1942. It may be that the position of the sour mountain grass veld has something to do with these

differences, as it lies on a mountain terrace a couple of hundred feet higher than the previous places used in the investigation made in the valleys. Mist was often hanging over the terrace till 11 a.m., and frequently mist rains descended very suddenly on it when a few minutes before there was blue sky. But apart from this the late season 1941/42 was decidedly wetter; there were seldom whole rainless days. All experience in South Africa shows that weather conditions affect transpiration to a large extent, perhaps only through the accumulation of water in the soil. Owing to the weather conditions the transpiration of the grasses was determined from the moment it began (which might be fairly late in the morning) till it stopped or at any rate, became very small; the transpiration was mostly cuticular.

RESULTS.

The attached Table 1 is only meant as preliminary information. The transpiration per day for a Spring day (S), and for a Summer day (A) is given in grs. per 1 gr. fresh matter, as well as the hourly mean transpiration, and the highest hourly value observed at the time. The data are compiled for each species (except for the spikes and the riverine formation) from 300-500 observations taken under the most different meteorological conditions. To understand the large variations, one has to study the connections between the obtained values and the prevailing meteorological conditions. When similar meteorological conditions are given, the transpirations per day for one species or even for a species which has similar leaves are strikingly alike.

The primary factors for the result are the *soil* and the *air moisture*, then the light. Temperature does not play a big rôle in the limits observed during the investigation. Air moisture is the factor governing the water output to the largest extent. It has been pointed out that mist was frequent in the rainy season, many days were experienced when, according to the luxmeter, transpiration could be expected, but the air was so laden with moisture that either transpiration did not take place or was limited to a few hours. On the other hand, when the soil has a high water content all the grasses transpire freely, if the air moisture permits it. During the mist or when after 11 a.m. the mist clears, very high hourly values are obtained. It often happened that with a sudden clearance of the mist the transpiration increased greatly within an hour and sank again when the mist closed in. One peculiar feature is that the higher values are often followed by a very low value for the next hour. In October and November the movement of the stomata was closely related to the rate of transpiration, presumably because all the leaves were very young, in March

no close agreement was observed. On the whole the stomata were wide open, to give the grass a chance of transpiration as soon as the meteorological factors permitted.

Of special interest is the influence of wind. Contrary to the effect on trees, wind has on grass at first an accelerating influence which is followed by a decrease. This is especially noticeable in the evening, when the mountain wind rises, for a short time after sunset. A low value obtained during the first hour is followed by a higher value in spite of decreasing light, but the next determination is again a low value, often zero.

As can be seen from Table 1 there are low transpiration values per day in the dry as well as in the wet season. Yet these values are arrived at in a very different manner. It was noticed that especially towards middle and end of November low transpiration values were obtained, that is when the soil moisture became less daily. It was most marked on the driest slope of the golf course towards the tree-fern valley. The stomata were closed or nearly closed in the afternoon. *Harpechloa Falx*, *Rendlia*, *Themeda*, *Monocymbium*, showed this type of transpiration.

The opposite behaviour of the stomata was observed during the low daily values in Autumn, which were all obtained on misty days. The stomata were open, but transpiration was hindered by the mist. If the sun penetrated very high hourly values were obtained.

As during 31 days there were only 16 days on which determinations could be made, sometimes only for a few hours, the other days being misty or heavy rains prevailing, it is clear that for the other 15 days the transpiration was nil. It is a very peculiar fact that in one and the same formation transpiration is restricted by either too much moisture in the air or too little moisture in the soil.

The riverine subsere of the sour mountain grass veld was not tested as often as the sour mountain grass veld itself. The species came up very late in Spring, and in the late Summer the soil was for days swampy after rains. *Cymbopogon validus* had a high transpiration except in misty weather. The species which grew equally well on the drier golf course as in the wet riverine subsere, *Rendlia*, *Themeda*, *Harpechlon Falx*, *Monocymbium*, *Tristachya hispida*, had a much higher transpiration value in the wet soil than on the golf course.

When it is asked whether any definite species showed a higher transpiration than others, or whether any definite seasonal variations were shown by a given species, the following can be stated: *Themeda triandra*, *Trachypogon plumosus*, *Elyonurus argenteus*, *Digitaria tricholaenoides*, *Harpechloa Falx*; *Eragrostis chalcantha*, have decidedly a

higher transpiration power early in the season, these are also the species which appear early. *Randlia Nelsonii*, and all the species appearing later in the season, show in late summer their highest transpiration. *Alleteropsis semialata*, the species which was tested the most, as being present in good conditions all the time, has the same transpiration power in both periods.

Broadly speaking the soft leaved grasses like *Digitaria tricholaenoides*, *Paspalum dilatatum*, *Tristachya hispida*, *Eragrostis chalcantha*, *Panicum Ecklonii* have higher mean hourly and higher maximum hourly values than the harder grasses. On the whole, especially in springtime, the roll leaves have a considerably smaller transpiration than the flat leaves; the roll leaves being *Andropogon* spp., *Elyonurus argenteus* and *Rendlia Nelsonii*. Moreover, the highest transpiration values in roll leaves are always found later in the day than those of flat leaves. This rule does not prevent an occasional high maximum hourly transpiration for *Elyonurus* or *Rendlia*, but it is rather the exception than the rule.

As was pointed out very few species had spikes and with the exception of *Trachypogon* the amount of spikes even for these species was very small. The spikes were tested at the same time as the leaves. They always showed a very small transpiration in spite of excellent moisture and light conditions. Actually they only transpire when they are very young. A few weeks old haulms scarcely show any transpiration. This being so, the water loss in the veld by haulms under the present management in the Drakensberg is negligible.

When the daily water output of these grasses is compared with that of indigenous trees of the area, the first striking difference is not so much the higher values for the grasses, as the fact that the indigenous trees with a few exceptions like *Leucosidea*, *Calpurnia*, *Rhus*, *Buddleia*, have distinctly small values for the dry season, although even then the soil is still wet in the forest, whilst the grasses even in a very dry soil may show some very large values. There is no doubt that in the rainy season some small trees show as large a transpiration power as the grasses, but never the large sclerophyllous trees.

To compare the water output per soil unit under trees and under grass, the figures previously obtained for the trees were used. For the grasses squares of different sizes were cut (from 1 x 1 yd.—5 x 5 yds., according to the amount of grass present), the species separated and weighed, and this was repeated in the different seasons, as the aspect changed. For each species the average

transpiration value per day for the season was used in calculation. Finally the whole values were recalculated for (100m)² to compare them with the values for the trees. According to observations and meteorological records, the grass began to grow in the drought period in October. Good rains set in in December, thus two months' drought values (October-November) have to be calculated, and 6 months wet season; as was pointed out previously transpiration took place on only 50% of the days in the wet season, thus the average transpiration value for each species for 90 days wet season has to be added. From end of May to end of September there is no green grass, consequently no transpiration. Two examples will explain the proceedings clearly. One patch is taken in the unburnt area of the veld, the other in the burnt area. A total of 9 patches were analysed in the same manner and gave the same result. In spite of the high transpiration of the grasses the result is very noteworthy. The area under grass transpires much more than the sclerophyllous trees, about as much as the same area under soft-leaved small trees like *Rhus dentata*, *Heteromorpha* and *Calpurnia*. A grass cover in place of an indigenous tree cover in water catchment areas does not necessarily mean a smaller loss of water.

The burnt area has a considerably higher water loss than the area which was protected from fire. The water loss of the area is about a third of that of an area of the rapidly transpiring trees like *Leucosidea sericea*, *Buddleia* and *Clausena*.

The author has been reproached that in the whole investigation of the transpiration of different formations no consideration was given to the economic aspect or even the beautifying aspect of any formation. It is felt, however, that these questions have nothing to do with a simple investigation of water loss. Again it must be emphasised that this investigation is concerned with the transpiration only, and as loss through transpiration has to be made good by an equal water intake through the roots from the soil to avoid a disturbance of the physiological balance, the two amounts are of the same order of size. That does not mean that at any moment of the day, loss of water by transpiration and intake are the same, on the contrary there is definite evidence that this is not so, that there is a water deficit in the grass leaves over the hot part of the day which shows itself in folding and curling of the leaves. But in the night the deficit is replaced. There was no means at Cathkin Park to ascertain the actual amount of the deficit, from data in another investigation however, it is known that it can be 35—40% without any damage to the grass (Henrici 1927), as long as it is only temporary in day-time.

TABLE I.

Plant		Transpiration per day	Hourly maximum transpiration	Mean hourly transpiration
<i>Themeda triandra</i>	S	3·41—11·70	0·64—2·39	0·28—0·97
	A	2·10—9·65	0·72—1·96	0·35—0·88
<i>Andropogon spec.</i> (Roll leaves)	S	2·05—5·15	0·39—1·04	0·17—0·43
	A	3·85—4·21	1·14—1·35	0·52—0·55
<i>Trachypogon plumosus</i>	S	3·40—9·59	0·82—1·47	0·31—0·80
	A	1·06—9·31	0·50—1·59	0·35—0·95
<i>Spike of Trachypogon</i>	A	0·49	0·23	0·10
<i>Elyonurus argenteus</i>	S	3·52—9·13	1·07—2·59	0·58—0·77
	A	1·45—6·17	0·50—1·11	0·36—0·56
<i>Digitaria tricholaenoides</i>	S	6·66—14·66	1·79—2·51	0·64—1·14
	A	7·56—10·00	1·49—1·51	0·69—1·00
<i>Monocymbium cerisiiforme</i>	A	2·82—12·67	1·08—3·35	0·32—1·15
<i>Spike of Monocymbium</i>	A	0·70—3·24	0·62—1·20	0·14—0·54
<i>Harpechloa Falx</i>	S	2·17—10·17	0·74—2·33	0·20—1·01
	A	1·16—5·43	0·49—1·10	0·15—0·49
<i>Rendlia Nelsonii</i> (Roll leaves)	S	3·18—4·68	0·99—1·93	0·42—0·53
	A	1·98—10·02	0·84—2·54	0·35—0·91
<i>Panicum Ecklonii</i>	S	6·39—6·67	1·80—2·01	0·57—1·11
	A	6·93—11·83	2·06—2·41	0·69—1·07
<i>Alleteropsis semialata</i>	S	3·81—15·76	0·69—3·63	0·34—1·31
	A	4·72—15·76	1·32—2·26	0·67—1·31
<i>Eragrostis chalcantha</i>	S	5·40—17·32	1·12—2·97	0·58—1·57
	A	2·89—14·11	0·93—2·47	0·66—1·28
<i>Eragrostis Hen. 3538</i>	A	1·86—13·25	0·65—2·23	0·46—1·20
<i>Spike of Eragrostis 3538</i>	A	3·42—4·46	1·39—1·47	0·40—0·43
<i>Tristachya hispida</i>	S	4·60—14·11	0·89—3·45	0·51—1·41
	A	4·07—12·80	1·25—2·33	0·58—1·17
<i>Cymbopogon validus</i>	S	7·05—15·06	0·93—2·57	0·88—1·50
	A	11·32	2·06	1·03
<i>Paspalum dilatatum</i>	A	12·17—16·14	2·16—2·51	1·21—1·99
<i>Spike of Paspalum</i>	A	3·87	0·83	0·35

TABLE II.

Spring determination	Unburnt Area	Average transpiration in grs. per day per 1gr. fresh matter.
In square 5×5 yards were found : ...	189 grs. <i>Alleteropsis</i> ... 117 .. <i>Trachypogon</i> ... 299 .. <i>Themeda</i> ... 1290 .. <i>Andropogon</i> , Roll leaves 74 .. Other grass, green ... 1866 .. Dry grass ...	9·22 6·17 7·84 3·82 7·00 0·0
In square 5 × 5 meters	3835 .. Grass	
In (100 m) ²	4586 .. Grass	
Transpiration of these	1834 kg. Grass	
1834 kg. grass per day	4886 kg. water	
Transpiration of the grass per 60 days	293200 kg. water in spring.	
Summer determination.		
Square directly adjoining the above : 3×3 yds. :	510 grs. <i>Trachypogon</i> ... 1986 .. <i>Elyonurus</i> ... 807 .. <i>Alleteropsis semialata</i> 20 .. <i>Tristachya leucotrix</i> ... 3 .. <i>Themeda triandra</i> ... 7 .. <i>Spikes, Trachypogon</i> 20 .. Other green leaves, not grass	4·11 4·07 7·50 6·88 4·23 0·49 2·00
In square 3×3 yards ...	3353 ..	
Yield in (100 m) ² ...	4447 kg. grass	
Transpiration of these	21667 kg. water	
4447 kg. grass per day	1950000 kg. water.	
Transpiration of the grass in 6 rainy months		
Total transpiration of 2 dry and 6 rainy months	2243200 kg water	

Spring determination.	Burnt Area. (On Mr. v.d. Merwe's farm.)	Average transpiration in gr. per day per 1 gr. fresh matter.
In 1 x 1 yard area were found :	15 grs. <i>Harpechloa Falc</i> ... 76 .. <i>Themeda triandra</i> ... 53 .. <i>Elyonurus argenteus</i> ... 31 .. <i>Tristachya hispida</i> ... 6 .. <i>Panicum Ecklonii</i> ... 11 .. <i>Eragrostis chalcantha</i> ... 16 .. other grasses ... 4 .. dry grasses ...	5.33 7.84 6.83 7.89 6.53 9.51 7.00 0.0
Per 100 x 100 yards ...	212 .. 2120 kg. grass.	
Per (100 m) ²	2535 ..	
Transpiration per day per (100 m) ²	= 18380 kg. water.	
Transpiration per 60 days per (100 m) ²	= 1102800 kg. water.	
Summer determination.		
In 2 x 2 yards exactly same place, were found	27 grs. <i>Harpechloa Falc</i> ... 269 .. <i>Rendlia Nelsonii</i> ... 89 .. <i>Monocymbium cerisiiforme</i> 583 .. <i>Andropogon</i> , roll leaves ... 519 .. <i>Themeda triandra</i> ... 468 .. <i>Tristachya hispida</i> ... 62 .. <i>Alleteropsis semialata</i> ... 423 .. <i>Trachypogon plumosus</i> ... 13 .. <i>Eragrostis chalcantha</i> ... 16 .. <i>Digitaria tricholaenoides</i> ... 32 .. Unknown grasses ... 90 .. Unknown non-grasses ...	3.19 4.57 6.12 4.03 4.23 6.88 7.5 4.11 7.41 8.78 4.0 2.0
Per (100 m) ²	2591 .. 7747 kg. grass.	
Transpiration per day per (100 m) ²	= 36850 kg.	
Transpiration per 180 days in the wet season per (100 m) ²	= 3316500 ..	
Do. In the dry season	= 1102800 ..	
Total in 8 months ...	4419300 kg.	

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THE GROSS MORPHOLOGY AND ARTERIAL SUPPLY
OF THE BRAIN OF THE GREY RODENT-MOLE
(CRYPTOMYS).

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INTRODUCTION: The rodent-moles of the genus *Cryptomys* exhibit in a marked degree the reduction of the visual apparatus which tends to occur in all animals adapted to a fossorial life. This specialisation is reflected by modifications of the brain structure, the unravelling of which may well throw light on the role of the visual mechanism in the normal mammalian brain. In this account, in addition to the gross architectural structure of the brain, the distribution of the superficial arteries has been examined in some detail, since several writers, particularly Shellshear (1929), have maintained that arterial distribution is not random, but morphologically constant and significant.

Cryptomys is grouped with the larger South African rodent-moles (*Bathyergus* and *Georychus*) in the family *Bathyergidae*. This family occupies a somewhat isolated position among rodents, due very largely to the domination of the structure in these animals by specialised habitus characters. The history of the family, which has existed in Southern Africa at least since the Miocene period, has been outlined by Broom (1934).

The moles used in this investigation were collected on the Witwatersrand, and in the opinion of Dr. A. Roberts are probably *C. natalensis* var. *jamesoni*. Two fixed specimens were used for the study of the general morphology; in one fresh specimen the arterial system was injected with a starch emulsion by the method of Scharrer (1940), permitting an examination of the finer divisions of the arterial distribution.

MORPHOLOGY OF THE BRAIN: Figures 1-5 show the general form of the brain in its several aspects. The cerebrum, 11.5 mms. in length, has a plump rounded contour with its greatest transverse measurement (15.6 mms.) near its posterior end. Viewed from above (Fig. 1), the posterior border of the cerebrum presents a shallow V-shaped indenta-

tion into which the anterior border of the cerebellum fits, hiding the corpora quadrigemina from view. The broad cerebellum consists of a high median vermis, 8 mms. long and 4 mms. broad, flanked by rounded hemispheres 4·4 mms. long and 3·7 mms. broad; the paraflocculus, though well developed, is completely overlapped and concealed by the cerebellar hemisphere in a dorsal view.

The topography of the basal aspect of the cerebrum and brain stem (Fig. 2) is complicated by the modification of the cranial nerves. While the optic nerve is very greatly reduced and the nerves to the eye muscles cannot be identified by gross dissection, the trigeminal nerve forms a massive trunk which in its forward course deeply indents the under side of the cerebrum. Similar modifications are seen in fossorial mammals as widely varied in systematic position as *Talpa* (Clark 1932) and *Notoryctes* (Burkitt 1938).

In dorsal and ventral view, the *olfactory bulbs* are pear-shaped, their lateral aspects being more boldly rounded than their closely approximated medial aspects. From the lateral aspect (Fig. 3) they present a more evenly rounded contour, while in a medial view (Fig. 4) this rounded mass is prolonged postero-inferiorly by a tapering extension through which the bulb is continued into the *tuberculum olfactorium*. In length the olfactory bulbs measure 3 mms.; in breadth 3·5 mms. each. The *fissura circularis*, which demarcates the bulb posteriorly, is well marked in the dorsal aspect. It becomes shallow as it descends both medially and laterally, until in the ventro-medial region it is practically non-existent, resulting in the confluence of the bulb with the olfactory tubercle. The olfactory nerve filaments enter the anterior surface of the bulb after piercing the very delicate cribriform plate. Behind the shallow infero-lateral extremity of the *sulcus circularis* the *lateral olfactory tract* (Fig. 2) commences in a low rounded elevation. From this it passes backwards as a distinct white band, broad at its commencement, but gradually narrowing as it is traced caudally. This tract bounds the olfactory tubercle, at whose posterior limit its tapering extremity curves sharply medialwards. The *tuberculum olfactorium* itself is an evenly rounded low convex elevation whose long axis is directed posteriorly and somewhat laterally. A small ill-defined *anterior perforated space* is found immediately behind the posterior pole of the olfactory tubercle.

On the lateral aspect of the cerebrum (Fig. 3) the *rhinal fissure* is represented by a shallow groove only about 2 mms. in length, proceeding backwards from the *fissura circularis*. This groove is directed posteriorly with a slight downwards convexity. Posteriorly, it fades away on the lateral border

of the hemisphere, so that there is no superficial demarcation of the pyriform lobe from the neopallium. There are no neopallial fissures.

The extremely slender *optic nerve* displays a most peculiar arrangement (Fig. 2) in that before reaching the base of the cerebrum it becomes divided into a medial and a lateral root. Of these, the medial is directed towards the midline as though to form an optic chiasma; however, such a crossing could not actually be identified. The lateral (un-crossed) root proceeds directly backwards and disappears under the medial border of the pyriform lobe, presenting in this region the usual relations of the optic tract. No superficial indication of a commissure of Gudden, as reported by Clark (1932) in *Talpa*, could be recognized.

In the absence of a distinct optic chiasma the tuber cinereum cannot be demarcated from the lamina terminalis. This region is represented on the basal aspect of the brain by two elongated elevations separated by a median groove. Posteriorly this groove fades out and the two elevations unite across the median line to form a transverse ridge, occupying the anterior part of the interpeduncular fossa and overlapped by the small cushion-shaped pituitary body. From its relations this transverse elevation appears to represent the *corpora mamillaria*. Posterior to it, in the interpeduncular fossa, is the *posterior perforated space*, completely hidden from ventral view by the pituitary gland.

The *corpus callosum* (Figs. 4, 5) measures 4·7 mms. in length and approximately 0·3 mm. in breadth. It has a well-marked genu; the rostrum ends as a rounded blunt projection pointing downwards and slightly backwards. The body, which is thinner than the genu, passes backwards and slightly upwards to the thick, rounded splenium. This is continuous with the posterior extremity of the *fornix*, which curves forwards and downwards and is thin, except at its splenial end and opposite the genu, where it thickens considerably. The ventral part of the fornix descends behind the *anterior commissure*, a relatively large oval structure tapering to a point dorsally. From the commissure the lamina terminalis runs down and backwards to become continuous with the mass of the tuber cinereum on the ventral surface of the brain. A tiny interventricular foramen intervenes between the column of the fornix and the rounded mass of the thalamus and hypothalamus which makes up the side wall of the third ventricle. The epithelial roof of the third ventricle and the pineal body could not be studied in any of the specimens.

The posterior surface of the cerebrum is a narrow area applied ventro-medially to the superior surface of the lamina

quadrigemina, supero-medially to the culmen of the cerebellar vermis, and laterally to the anterior surface of the cerebellar hemisphere. On the deeply concave ventro-medial surface (Fig. 5) the fimbria appears as a slightly elevated white band curving boldly upwards, outwards, and forwards, to splay out as it reaches the fornix. The dentate gyrus is so deeply indented as to produce superficially the appearance of three separate islets. The smooth extraventricular alveus, between the fimbria and the dentate gyrus, expands below into the well-defined hippocampal tubercle.

In median section (Fig. 4) the *lamina quadrigemina* forms a wedge-shaped mass projecting dorsally between the cerebrum and the cerebellum. There is no distinct differentiation of anterior and posterior colliculi. Comparison with the same region in rodents with normal vision indicates that this appearance results from the retrogression of the anterior colliculi. The condition is closely similar to that figured by Clark (1932) in *Talpa*. It appears also as though there is a shortening of the whole mesencephalic region, but there is not the abrupt flexure of the brain in this region seen in *Notoryctes* (Burkitt, 1938).

Ventrally (Fig. 2), the *cerebral peduncles* are seen as two short stout columns of fibres which issue from the inferior surface of the cerebral hemispheres and pass postero-laterally to plunge into the pons. They are demarcated from the pontine part of the hind-brain by a slight ridge formed by the superficial transverse fibres of the *pons*. On either side these fibres form a broad compact strand—the *brachium pontis*—which sinks backwards and laterally into the cerebellar hemisphere. Posteriorly the transverse fibres thin out considerably so that no clear line divides the pons from the medulla oblongata.

Here again the specialised modifications of the cranial nerves confuse the topography. While none of the nerves to the ocular muscles could be identified, the trigeminal nerve forms a massive trunk smothering the ventro-lateral part of the pontine region. Lateral to the interpeduncular fossa this trunk displays an oval expansion, the *semilunar* (Gasserian) ganglion. From this it breaks up into two divisions. The anterior division consists of the conjoined ophthalmic and maxillary branches, which part company only at the posterior border of the piriform lobe. The posterior division, which is the mandibular branch of the nerve, divides almost immediately into two portions.

Just posterior to the origin of the trigeminal trunk a smaller but still considerable nerve trunk arises far dorsally on the lateral aspect of the hind-brain, just anterior to the stalk of the paraflocculus. This certainly represents the auditory nerve, and may also include the facial nerve. Its

origin may be taken as marking the anterior limit of the medulla oblongata.

The *cerebellum* covers the dorsal surface of the pons and the anterior portion of the medulla oblongata. In a dorsal view the vermis, which is differentiated from the hemispheres by broad shallow grooves, is subdivided by three transverse fissures. These are from before backwards the *fissura prima*, the *sulcus praepyramidalis*, and the *fissura secunda*.

In median section the vermis shows an arrangement of folia almost identical with that of the mouse (v. Hallerstein 1934). The rounded hemisphere is divided in its lateral part by radiating fissures into six segments. Ventral to the hemisphere is the rounded, unsubdivided paraflocculus. This, although continuous with the posterior lobe of the vermis, extends well forwards, almost touching the posterior extremity of the cerebrum.

This brain may be compared with those of other fossorial mammals of closely similar habitus, but belonging to widely different orders, viz., the Marsupial Notoryctes (Burkitt 1938) and the Insectivores Talpa, Scalops and Chrysochloris (Clark 1932). Some of the correspondences and differences in detail have been noted in the course of this description. In its general morphology, the brain of Cryptomys does not show the peculiar modification is shared by Notoryctes and Chrysochloris, appearing more readily comparable with that of Talpa.

VASCULAR PATTERN: The arterial supply of this brain is apparently derived entirely from the vertebral arteries. No connection of the internal carotid arteries with the circulus arteriosus could be demonstrated. This arrangement, which is found in some other rodents (Beddard 1904), must be regarded as a specialised one, the vertebral arteries being of more recent formation than either the carotid or the spinal arteries (Shellshear 1929). The *vertebral artery* is therefore of considerable size (Fig. 2). It meets its fellow in the mid-line on the ventral surface of the medulla, to form the *basilar artery*. The two vertebral arteries are equal in size and are symmetrical. From the medial aspect of each arises a small vessel directed medially and caudally, which ends by joining with its fellow of the other side, to form the *anterior spinal artery*. This runs caudally in the midline on the ventral surface of the spinal cord, giving off tiny lateral branches throughout its course. From the lateral aspect of the vertebral artery arises a vessel approximately equal in size to the anterior spinal artery. On the side of the medulla this vessel divides into two or three main branches, which ramify on the dorsal surface of this region.

The *basilar artery* causes a marked indentation along the midline of the ventral surface of the pons. It gives off

several branches on either side; two of these are large, the remainder being the small pontine arteries which enter the ventral surface of the brain adjacent to the main artery.

The first large branch, the *posterior inferior cerebellar artery* (Figs. 1, 2, 3), arises at the confluence of the vertebral arteries, that is, at the actual origin of the basilar artery. These vessels arise almost symmetrically, the left slightly more cranially than the right. Proceeding laterally around the medulla, the artery comes to lie in the middle of the posterior surface of the cerebellar hemisphere, where it splits into two main branches, a lateral and a medial. The lateral and slightly larger proceeds outwards to ramify on the lateral surface and lateral half of the dorsal surface of the cerebellar hemisphere. The medial branch continues in the line of the parent vessel and divides to supply the medial half of the dorsal surface of the hemisphere and part of the adjacent vermis. Thus the posterior inferior cerebellar artery is the main arterial trunk to the cerebellum.

The second large branch, arising from the basilar artery at about the middle of its length, passes laterally behind the origin of the trigeminal trunk, to approach the origin of the auditory nerve (Fig. 2). Just ventral to this nerve the artery divides into two branches. The posterior and larger of these appears to have accompanied the nerve, and must, therefore, be the *internal auditory artery*. The lesser branch continues dorsalwards, passing anterior to the root of the nerve, and reaches the ventro-lateral surface of the paraflocculus over which it ramifies. This parafloccular branch is the sole representative in this brain of the *anterior inferior cerebellar artery*. The origin of this artery by a common stem with the internal auditory is not surprising in the light of Shellshear's (1929) observations on the intimate relationship between these vessels.

In the interpeduncular fossa the basilar artery divides into two symmetrical branches, which correspond to the stems of the posterior cerebral arteries in the normal circulus arteriosus. Voris (1928) terms these stems in *Didelphys* the "right and left basilar arteries." Considering that in Cryptomys the blood-supply of the entire cerebrum is derived from these vessels, the name *Cerebral Trunks* is suggested as more appropriate in this case. The cerebral trunk proceeds laterally from its origin, curving slightly forwards to end under cover of the Gasserian ganglion by dividing into two main branches. Its larger anterior branch is the equivalent of the posterior communicating artery; the smaller posterior one is the true posterior cerebral artery.

The "posterior communicating artery" (Fig. 2), emerging from under cover of the trigeminal nerve, proceeds directly anteriorly to end at the posterior border of the

olfactory tubercle by dividing into the anterior and the middle cerebral arteries. At about the middle of its course a lateral branch, supplying a small area of the piriform lobe lateral to the artery, was found on the right side of the injected brain.

From its origin, the *anterior cerebral artery* extends forwards and inwards over the postero-medial part of the tuberculum olfactorum, turning forwards to run parallel to the midline. Passing medial to the base of the olfactory bulb it sweeps dorsally on to the medial surface of the hemisphere. Arching backwards dorsal to the corpus callosum (Fig. 4), it ends above the splenium by dividing into two branches. One of these passes towards the occipital pole; the other curves ventrally under the splenium. In its course the anterior cerebral artery gives off several large branches. The first (Fig. 2) comes off as the main artery crosses the olfactory tubercle, and passing antero-laterally splits up into several twigs. Some of these go laterally across the lateral olfactory tract; others pass more anteriorly on to the rounded eminence from which the lateral olfactory tract originates, and even, on the right side of the injected brain, on to the base of the olfactory bulb. This "ventral olfactory artery" probably is or incorporates that which Shellshear (1929) refers to as "Heubner's artery."

The next branch of the anterior cerebral artery comes off on the medial surface of the hemisphere level with the rostrum of the corpus callosum (Fig. 4). It curves forwards towards the frontal pole, giving off many branches to the frontal region of the cerebrum, to end on the medial and dorsal surfaces of the olfactory bulb as a "medial olfactory artery."

Above the genu of the corpus callosum two branches arise close together and pass dorsally. They anastomose about half way up the medial surface of the hemisphere, the more anterior artery having previously given off a branch which extends anteriorly on to the dorsum; the combined trunk inclines posteriorly to reach the dorsal surface of the cerebrum. The last branch, which comes off just before the artery reaches the splenium, and is a little smaller than the others, runs posteriorly as well as dorsally. These branches of the anterior cerebral artery which reach the dorsum of the brain supply the medial one-quarter of that surface. The actual termination of the artery extends over the medial one-third of the posterior region of the dorsum. An anterior communicating artery was not found in the injected brain.

The stem of the *middle cerebral artery* (Fig. 2) travels antero-laterally, and commences to divide before reaching the lateral olfactory tract. This division does not take place symmetrically on the two sides of the injected brain. In

both cases three divisions are ultimately formed, but on one side the anterior and middle divisions arise from a common trunk, on the other the middle and posterior divisions. However, the three divisions, once formed, are quite symmetrical in their distribution (Fig. 3). The anterior division is directed forwards and upwards towards the frontal pole, passing a little above the rhinal fissure. It gives off two major ascending branches which pass dorsally over the frontal region, and a horizontal branch distributed along the rhinal fissure. The terminal portion of the artery ramifies over the superior and lateral surface of the olfactory bulb. This structure has thus an arterial supply from two sources, the anterior cerebral artery supplying the inferior and medial aspects, the middle cerebral the superior and lateral.

The middle division proceeds dorsally and slightly posteriorly over the lateral aspect of the cerebral hemisphere, to ramify on the middle of the dorsal surface.

The posterior division of the middle cerebral artery courses dorsally and posteriorly and ends in fine twigs on the posterior third of the dorsum of the cerebral cortex. Several branches are given off in its course, the largest of which comes off ventrally and runs backwards and downwards, to terminate over the postero-inferior surface of the lateral aspect of the cerebral hemisphere.

The smaller posterior branch of the cerebral trunk, the *posterior cerebral artery*, proceeds from its origin laterally and slightly posteriorly (Fig. 2). Under cover of the trigeminal nerve it winds round the cerebral peduncle on to the lateral surface of the midbrain and curving slightly forwards reaches the anterior surface of the corpora quadrigemina. There it terminates by dividing into several large branches which spread over the corpora quadrigemina, continue on to the thalamus, or sweep upwards and backwards to reach the ventro-medial surface of the cerebral hemisphere.

A branch arising from the main artery just before it reaches the lateral aspect of the midbrain, passes dorsally and backwards on to the anterior surface of the cerebellar hemisphere. Its terminal twigs are distributed dorsally and medially over the anterior surface of the cerebellum. This branch must be regarded as the *superior cerebellar artery*.

Of the terminal branches, the first travels forwards for some little distance on the upper part of the lateral surface of the midbrain and then, with a sweeping curve, goes on to the inner surface of the posterior part of the cerebral hemisphere. Here it breaks up into twigs, some of which extend backwards on to the posterior surface of the cerebral hemisphere.

The next branch, lying dorsal to the previous one, passes along the base of the anterior surface of the corpora quadrigemina, to ramify finally on the dorsum of the thalamus. Posterior to this branch, another extends on to the dorsum and posterior surface of the lamina quadrigemina, where it ends as fine twigs. The final branch, continuing in the direction of the parent vessel, ramifies over the anterior surface of the lamina quadrigemina where it appears to have a rich anastomosis with the vessels from the other side.

Shellshear (1929) argues that the posterior cerebral artery in mammals has progressively captured the arterial supply of all the visual centres, mesencephalic, thalamic and cortical. In *Cryptomys* this development appears to have reached an advanced stage. From this it might be inferred that this type is descended from one with a highly integrated visual mechanism.

SUMMARY: The brain of *Cryptomys* does not exhibit the marked deformation seen in *Notoryctes* and *Chrysochloris*. As in other fossorial mammals, the cranial nerves are greatly modified. The much atrophied optic nerve divides into a lateral and a medial root; the former follows the course of the optic tract in normal brains, the latter proceeds towards the middle line, but an actual chiasma was not demonstrated. None of the nerves to the orbital muscles could be demonstrated. On the other hand the trigeminal nerve is very large. The rounded cerebrum is very smooth, even the rhinal fissure being greatly abbreviated. Owing to the reduction of the anterior colliculi the lamina quadrigemina is of peculiar form; it is completely overlapped by the cerebrum and the cerebellum. The large cerebellum is of a simple character.

The arterial supply of the brain is derived wholly from the vertebral arteries, a specialised arrangement of secondary origin. The posterior inferior cerebellar artery, arising from the confluence of the vertebral arteries, forms the main channel to the cerebellum. From the basilar artery the internal auditory and anterior inferior cerebellar arteries arise by a common stem; the latter supplies only the region of the paraflocculus. At its anterior end the basilar artery bifurcates to form two vessels, here termed the cerebral trunks. Each of these divides into a posterior cerebral artery and a vessel corresponding to the posterior communicating artery; this latter divides at its anterior end into anterior and middle cerebral arteries. The anterior cerebral artery supplies the area of the tuberculum olfactorium, the ventral and medial aspects of the olfactory bulb, the whole medial surface of the cerebral cortex to the occipital pole, and the medial one-fourth of its dorsal surface. No anterior communicating artery has been observed. The middle cerebral

artery supplies the remainder of the superior and lateral surfaces of the cortex, together with the superior and lateral aspects of the olfactory bulb; thus the bulb receives a supply from both the anterior and middle cerebral arteries. From the posterior cerebral artery a superior cerebellar artery is first given off, after which it breaks up into a series of branches supplying the ventro-medial surface of the cerebral hemisphere, the thalamus and the lamina quadrigemina.

In conclusion, I wish to thank Professor R. A. Dart for the opportunity of making this study in his department.

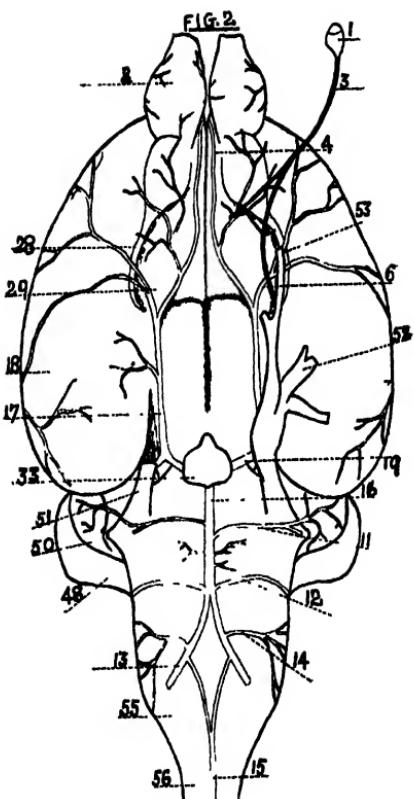
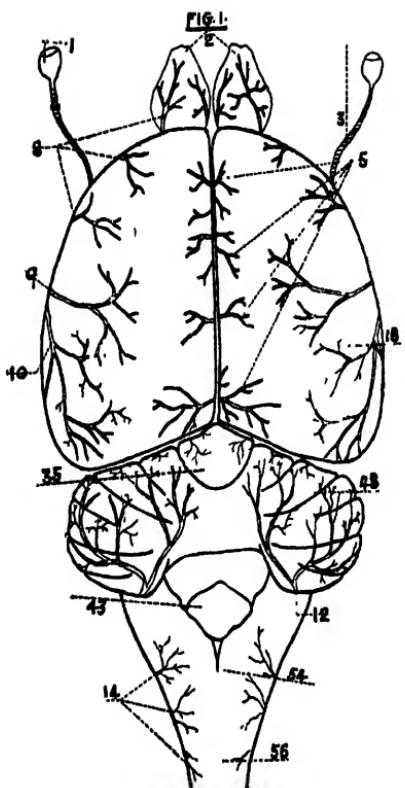
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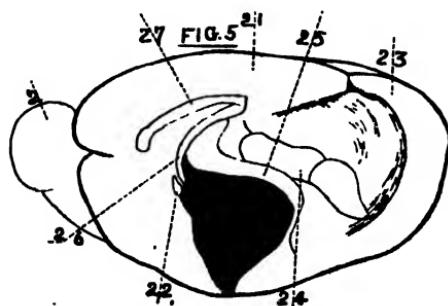
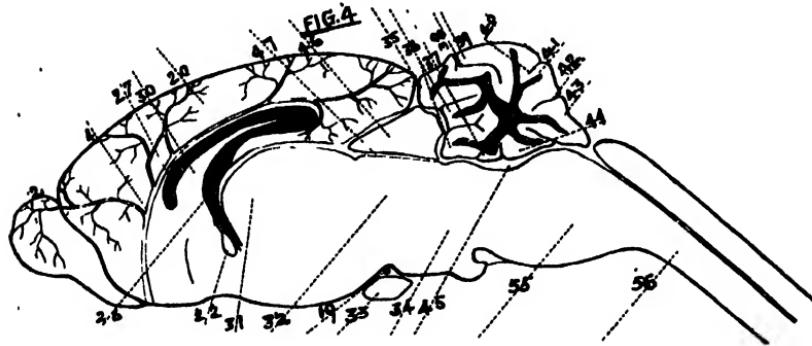
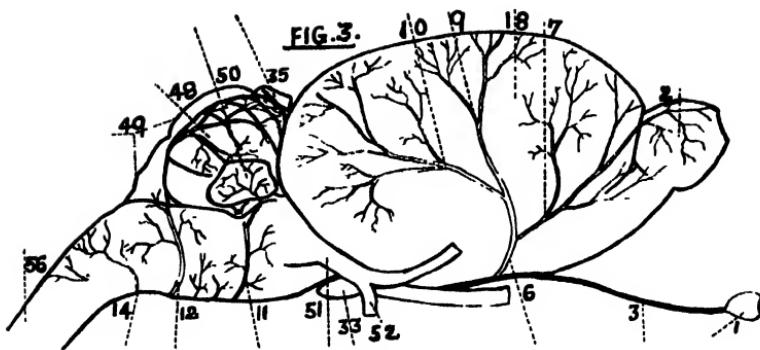
- BEDDARD, F. E.: On the Arteries of the Base of the Brain in certain Mammals. *Proc. Zool. Soc.* 183-197 (1904).
- BROOM, R.: On the fossil remains associated with *Australopithecus africanus*. This Journal. **31**, 471-480 (1934).
- BURKITT, A. N.: The external morphology of the brain of *Notoryctes typhlops*. *Proc. Kon. Wetenschappen Amsterdam.* **XLI**, 1-15 (1938).
- CLARK, W. E. LE GROS: The Brain of the Insectivora. *Proc. Zool. Soc.* 975-1013 (1932).
- SCHARRER, E.: Arteries and Veins in the Mammalian Brain. *Anat. Rec.* **78**, 173-196 (1940).
- SHILLSHEAR, J. L.: A study of the arteries of the brain of the Spiny Anteater (*Echidna Aculeata*), to illustrate the Principles of Arterial Distribution. *Phil. Trans., Series B*, **218**, 1-36 (1929).
- VORIS, H. C.: The arterial supply of the Brain and Spinal Cord of the Virginian Opossum (*Didelphis virginiana*). *Journ. Comp. Neur.* **44**, 403-423 (1928).

INDEX TO ILLUSTRATIONS.

Fig. 1.—Brain of Cryptomys. Dorsal view; Fig. 2.—do. Ventral view; Fig. 3.—do. Lateral view; Fig. 4.—do. Medial view; Fig. 5.—do. Medial view of Cerebral Hemisphere with midbrain removed.

(1) Eye; (2) Olfactory Bulbs; (3) Optic Nerve; (4) Anterior Cerebral Artery; (5) Branches from Anterior Cerebral Artery; (6) Middle Cerebral Artery; (7) Middle Cerebral Artery, Anterior Branch; (8) Arteries from Anterior Branch of Middle Cerebral Artery; (9) Middle Branch of Middle Cerebral Artery; (10) Posterior Branch of Middle Cerebral Artery; (11) Anterior Inferior Cerebellar Artery; (12) Posterior Inferior Cerebellar Artery; (13) Vertebral Artery; (14) Lateral Branches of Vertebral Artery; (15) Anterior Spinal Artery; (16) Basilar Artery; (17) Posterior Communicating Artery; (18) Cerebral Hemisphere; (19) do. Trunk; (20) do. Lobe; (21) do. Medial Surface; (22) do. Anterior Commissure; (23) do. Posterior surface; (24) do. Dentate Gyrus; (25) do. Fimbria; (26) do. Fornix; (27) do. Corpus Callosum, (28) Lateral Olfactory Tract; (29) Tuberulum Olfactorium; (30) Septum Pellucidum; (31) Thalamus; (32) Tegmentum; (33) Pituitary Gland; (34) Pons; (35) Lobus Anterior-Culmen; (36) Lobus Centralis; (37) Lobus Anterior-Lingula; (38) Fissura Prima; (39) Lobus Medius; (40) Sulcus praepyramidalis; (41) Pyramis; (42) Fissura Secunda; (43) Uvula; (44) Nodulus; (45) Fourth Ventricle; (46) Corpora Quadrigemina (Tectum); (47) Aqueduct of Sylvius; (48) Cerebellum, Lateral Hemisphere; (49) Vermis; (50) Paraflocculus; (51) Trigeminal Trunk; (52) Mandibular Division of Trigeminal; (53) Maxillary Division of Trigeminal; (54) Calamus Scriptorius; (55) Medulla (56) Spinal Cord.





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FOSSIL MAMMALIAN REMAINS FROM BANKIES.
KROONSTAD DISTRICT, O.F.S.

BY

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Read 30th June, 1942.

I. INTRODUCTION: The collection of fossil remains, with which this paper deals, was sent to this Department in September 1936, by Mr. G. Myburgh, who found them on his farm at Bankies, near Kroonstad, in a lime-patch, 20 yds. x 30 yds. in extent. An overburden of soil about 15" thick covered the lime deposit, which was 4' deep.

At that time, owing to the state of our knowledge of Pleistocene geological horizons and faunas in South Africa, a full interpretation of this find was not possible, but it can now be considered against its proper background in the light of recent studies culminating in the comprehensive survey of Cooke (1941).

On re-examining this small collection, nine distinct types were observed, and as such an association of types has only been found in a few sites, such as Florisbad, Cornelia, and the Wonderwork cave, the details have here been noted.

II. THE FAUNAL REMAINS: The collection contains about forty fragments of bones, loose teeth and portions of horn-cores, for the most part well fossilised. Specific identifications have been based principally on teeth and, to a lesser extent, on horn-cores. The bone fragments are capable at most of generic identification, but may reasonably be ascribed to those forms which have been determined on the basis of teeth and horn-cores.

ORDER: CARNIVORA: Two large lower canine teeth, 23 mm. in antero-posterior length and 16 mm. in labio-lingual breadth at the base of the crown, are the only carnivore material in the collection. These canines have the same general appearance as those of the hyena, but are much larger, more closely resembling those of the lion though slightly smaller. They appear, however, to fall within the normal range of variation of this form.

ORDER: PERISSODACTYLA: Fam. Equidae. The majority of the equine remains consist of upper and lower cheek teeth,

which lend themselves to ready identification; unprofitable material is however present in the form of one proximal phalanx and one upper incisor.

Equus quagga (Gmelin). Cooke (Malan and Cooke, 1941) has expressed the opinion that it is possible, by means of dental characters, to differentiate the true quagga (*E. quagga*) from the bontequagga (*E. burchelli*). The criteria upon which he bases this distinction are not stated in the paper referred to, but I have been permitted to draw upon an unpublished memoir by Mr. Cooke.

Three right upper teeth, P₃-M₁, one left upper second molar, right first and third mandibular molars, and a fragment of a lower premolar show the features regarded as characteristic of *E. Quagga*. The lower teeth probably pertain to the same individual as the three consecutive upper teeth, being of the same calibre and texture as those teeth.

The caballine fold is well-developed except in the first molar, where its presence is indicated only by a slight crimping of the enamel. The average transverse diameter for the upper teeth is 25 mm. and for the lowers 13 mm.

One left upper first or second molar in an early state of wear is also referred here. The antero-posterior length of the crown of this tooth is 25 mm. greater than that of the abovementioned second molar; this would allow for the rapid decrease in antero-posterior length which takes place during wear.

Equus burchelli (Gray). Upper cheek teeth, presenting the differential characters of the bontequagga, comprise a third and fourth premolar and a first and second molar, all of the left side. The crowns were heavily covered with cement and, when cleaned, showed no signs of secondary enamel plications or of a caballine fold.

One lower second molar and a fragment of a second or third lower premolar are also referred to this species.

The upper teeth have an average transverse diameter of 22.5 mm. and the lowers, 12.5 mm.

Equus capensis (Broom). One right upper first molar, 70 mm. in height, 34 mm. in both transverse and antero-posterior diameters, conforms reasonably well, both in dimensions and the more constant enamel folds, to teeth ascribed to this species by Broom (1913), Haughton (1932), and Broom and le Riche (1936).

Cooke (Malan and Cooke, 1941) on the evidence of associated upper and lower teeth from the Wonderwerk cave, has argued that the type of *E. caewoodi* Broom represents the upper dentition of *E. capensis* in an early stage of wear. The characters displayed by the material at present at my

disposal would seem to cast considerable doubt on the validity of this interpretation. This does not however affect the determination of the Bankies tooth as *E. capensis*, as this tooth resembles specimens referred to *E. capensis* much more than it does the type of *E. cawoodi*.

ORDR: ARTIODACTYLA: FAM: SUIDAE. *Phacochoerus aethiopicus* (Pallas). One complete right lower third molar and fragments of three upper third molars show the characteristic pattern of the Phacochoere third molar.

The lower molar is 43 mm. in height (measured at the anterior set of columns) and has an occlusal length of 47 mm. and an occlusal width of 10·5 mm. The posterior columns have already come into wear but no signs of root development are evident. The tooth may therefore be taken to represent *P. Aethiopicus* (E. C. N. and H. E. van Hoepen, 1942; Shaw, 1939).

The fragments of upper teeth average 10 mm. in transverse diameter. It is noteworthy that, despite this small transverse diameter, one of these fragments possesses two accessory median columns. Since these fragments are of the more posterior portions of the tooth specific identification is not possible. However, the association may be regarded as sufficient evidence for assigning these teeth to *P. aethiopicus*.

Similarly a large practically complete upper canine, 170 mm. in point to base length and 50 mm. in transverse diameter at the base, may also be referred to *P. aethiopicus*.

FAM: BOVIDAE: The bovine material in this collection consists of bones, teeth and horn-cores of at least four different genera.

"*Bubalus*" cf. *bainii* (Seeley). One first or second upper and one third lower molar are larger than the corresponding teeth of the Cape Buffalo (*Syncerus caffer*) and of slightly different enamel pattern from those teeth. They may therefore be tentatively assigned to *B. bainii*.

The upper molar measures 37 mm. along the outer enamel plate and the lower 48 mm. in comparison with 28 mm. and 41 mm. for the corresponding teeth of the Cape Buffalo.

Three fragments of lower molars show marked resemblance to the lower molar mentioned above.

Peloroceras helmei (Lyle). A fragment of a right lower third molar corresponds in size and enamel pattern with the teeth from the Wonderwerk cave which Cooke (Malan and Cooke, 1941) has ascribed to this type, being closely similar in pattern to those of the hartebeest, but much larger. This assumption is supported by the presence of teeth of

identical character among material from Florisbad, the type locality, in the South African Museum.

Terminal portions of two horn-cores appear to correspond to van Hoepen's (1932) description as regards the backward twist and curve of this genus and species; however the specimens are not sufficiently complete for certain identification.

Damaliscus cf. *albifrons* (Burchell). One upper molar and two fragments of lower molars are definitely of damaliscine character and would appear to be those of the blesbok, which is indigenous to this area.

Connochaetes sp. One complete upper molar and five fragments of lower molars correspond to those of the Wildebeest. Specific identification is not however possible. In addition to the two recent species *C. gnou* and *C. (Gorgon) taurinus*, two fossil species, *C. antiquus* Broom and *C. (Gorgon) laticornutus* van Hoepen, have been described on horn-cores. No account of the differential features of the dentition in these forms has been published, so that at present it is impossible to base specific identifications on teeth alone.

It is also possible that some at least of the fragments of horn-cores in the collection belong to *Connochaetes* rather than to *Peloroceras*.

The bones comprise: 1. Three tali, averaging 60 mm. in antero-posterior length and 35 mm. in transverse breadth. referable to the medium sized bovids, such as *Connochaetes* whose presence in the collection has been determined by tooth characters. 2. Two larger tali, 100 mm. in length and 65 mm. in transverse breadth, associated with fragments of two tibiae, belonging to very large bovids, e.g. "*Bubalus*" *Bainii* or possibly *Peloroceras*.

III. DISCUSSION: Unfortunately no human artifacts accompany the faunal remains; if any were present in the deposit, they must have passed unrecognised. It is thus not possible to correlate these remains directly with the archaeological sequence in South Africa. Nevertheless a probable geological horizon, deduced from geological and faunal evidence, may be assigned to the deposit at Bankies.

The nine species identified include at least three forms (*Equus capensis*, *Peloroceras helmei*, and the bovid described as "*Bubalus*" cf. *Bainii*) which are not members of the present day South African fauna. Cooke, Malan and Wells, in a communication to the Royal Society of South Africa during 1941, have pointed out that, while these species have been found associated with Middle Stone Age industries they have not yet been recorded in definite association with Later Stone Age artifacts. These authors continue:

"Moreover there is evidence of a distinct climatic break, which appears to coincide with (and possibly to determine) the

end of the Middle Stone Age. Since we have excellent evidence that many now extinct animal forms lived during late Middle Stone Age times, while no extinct forms have been found with the Later Stone Age, we may suspect that the increasing aridity at the end of the Middle Stone Age was responsible for the extinction itself. On these grounds it appears reasonable to regard this climatic break at the end of the Middle Stone Age as marking the end of the Pleistocene in southern Africa The Later Stone Age with its impoverished fauna would accordingly be regarded as falling within the Holocene."

If this view be accepted, the Bankies fauna would be referable at latest to the terminal phase of the pleistocene.

Support for this interpretation is provided by a further consideration. Cooke (1941) has observed that the climatic break occurring at the close of the Middle Stone Age (and marking the end of the Pleistocene) is represented by a characteristic old land surface, a foot or more below the present level. It appears quite possible, as Mr. Cooke has pointed out to us, that the upper surface of the lime patch at Bankies, lying some fifteen inches below ground level, coincided with this old land surface. In Mr. Cooke's opinion, such a localized lime patch represents the drying up of a pan or waterhole. The evidence while not conclusive is strongly in favour of a Late Upper Pleistocene age for the Bankies deposit.

All the forms identified at Bankies either have been recorded at one or more of the more important Free State deposits or are known to have been members of the recent highveld fauna. The presence of the true quagga in association with Middle Stone Age deposits has hitherto been regarded as uncertain (Cooke, 1941), although it occurred side by side with *E. burchelli* at Wonderwerk.

The Bankies collection, except for the presence of the large extinct forms, is one typically representative of the modern highveld. It accords therefore with the inference drawn by Cooke, Malan and Wells in the paper cited above, that the physical conditions prevailing in this area during the terminal phase of the Pleistocene, were not greatly different from those of the present day.

ACKNOWLEDGMENTS.

The writer wishes to thank Professor R. A. Dart, in whose department the facilities for carrying out the work were provided; Dr. L. H. Wells, of the Department of Anatomy, for reading the manuscript and for many helpful suggestions and criticisms; Mr. H. B. S. Cooke for permission to use his unpublished manuscript and for his valuable comments concerning the geology of the deposit.

On behalf of the Department of Anatomy, I wish also to thank Mr. G. Myburgh, to whom we are indebted for the material.

ADDENDUM: This department possesses three teeth obtained from a sub-surface lime deposit near Wolmaranstad. This material corresponds closely in character and occurrence to that from Bankies. One of the Wolmaranstad teeth is an Hyaenid third upper premolar which may be tentatively assigned as cf. *Crocuta crocata* (Erxleben). The other two are equine upper cheek teeth. One of these, a left fourth premolar, just coming into full wear, measures 34 mm. in transverse diameter and may be confidently assigned to *E. capensis*; it agrees remarkably with the first molar figured by Broom and le Riche (1936). The remaining tooth, a right fourth premolar, is almost unworn, measures 27 mm. in transverse diameter and has been tentatively identified as *Equus* cf. *kuhni* (Broom). The presence of these two extinct horses in a similar deposit at Wolmaranstad thus supports the conclusion reached in the discussion of the Bankies collection that these sub-surface lime deposits are of Pleistocene age.

REFERENCES.

- BROOM, R.: Note on *Equus Capensis*, Broom, *Bull Am. Mus. Nat. Hist.*, **32**, 437-439 (1913).
- BROOM, R., AND LE RICHE, H.: The Dentition of *Equus Capensis*, Broom. This Journal. **XXXIII**, 759, 760 (1936).
- COOKE, H. B. S.: A Preliminary Survey of the Quaternary Period in South Africa, *Arch. Serv.*, IV, Bureau of Archaeology, Govt. Printer, Pretoria (1941).
- COOKE, H. B. S., MALAN, B. D., AND WELLS, L. H.: The associated fauna and Culture at the Vlakkraal Thermal Springs, O.F.S., *Trans. Roy. Soc. S. Afr.* **XXIX** (in press), (1942).
- DREYER, T. F., AND LYLE, ALICE: *New Fossil Mammals and Man from South Africa*, Dept. Zoology, Grey Univ. Coll., Bloemfontein (1931).
- HAUGHTON, S. H.: The Fossil Equidae of South Africa. *Ann. S.A. Mus.* **XXVIII**, 407-427 (1932).
- MALAN, B. D., AND COOKE, H. B. S.: A Preliminary Account of the Wonderwerk Cave, Kuruman District. This Journal. **XXXVII**, 300-312 (1941).
- SHAW, J. C. M.: Growth Changes and Variations in Wart-hog Third Molars and their Palaeontological importance, *Trans. Roy. Soc. S. Afr.* **XXVI**, 51-94 (1939).
- VAN HOEPEN, E. C. N.: Fossiele Perde van Cornelis, Q.V.S., *Pal. Nav. Nas. Mus. Bloemfontein, Deel II*, (2), (1930).
- VAN HOEPEN, E. C. N.: Voorlopige Beskrywing van Vrystaatse Soogdiere, *Pal. Nav. Nas. Mus. Bloemfontein, Deel II*, (5), (1932).
- VAN HOEPEN, E. C. N., AND VAN HOEPEN, H. E.: Vrystaatse Wilde Varke, *Pal. Nav. Nas. Mus. Bloemfontein, Deel II*, (4). (1932).

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THE CRANIAL MORPHOLOGY OF THE NEOTROPICAL
MICROHYLID (ANURA) *ELACHISTOCLEIS OVALIS*
(SCHNEIDER).

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INTRODUCTION.

The most comprehensive work on the group of frogs formerly referred to by Gadow (1901) as the *Engystomatidae* and by Noble (1922) as the *Brevicipitidae* has been done by H. W. Parker in 1934, who has created the family *Microhylidae* for the reception of what he regards as the true members of this group. For a detailed history of the family the reader is referred to Parker's monograph. In the present connection it is interesting to note that the sub-family *Microhylinae*, in which *Elachistocleis ovalis* is included, has been expanded by Parker to include Noble's original *Brevicipitinae*, as well as Noble's *Cacopinae*, *Kaloulinae*, *Kalophryninae* and *Microhylinae*. The sub-family so constituted has a wide distribution over North and South America, the Indo-Australian archipelago and Asia.

The specimen used for this investigation was collected by Antenor Lutoo de Carvalho and sent to us with the appellation, "Elachistocleis ovale bicolor, val Salobna E. de Matto, Brazil."

The genus *Elachistocleis* was first described in 1799 by Schneider as *Rana*. Subsequently the generic name was changed several times until, in 1927, Parker instituted the name *Elachistocleis*. The type specimen was referred to by Schneider as *Rana ovalis*, but later on several different specific names were applied to it. Parker, in 1927, adopted the name *Elachistocleis ovale ovale* which, in 1931, was changed by Crawford to *Elachistocleis ovalis*.

A description of the external features of *Elachistocleis ovalis* will be found in Parker (op. cit. pp. 121-122). According to him the genus occurs from Panama southwards, east of the Andes to Buenos Aires, and in Trinidad. He mentions two colour varieties, the *bicolor* type and the typical *ovalis* type, and states that they may prove to be two distinct species, although Mertens (1929) regards them as colour

mutants of the same species. In a recent personal communication, however, Mr. Parker has volunteered the following interesting information: Müller and Helmich (Wiss. Ergeb. Deutsch. Gran-Chaco Exp., Amph. and Rept., 1, 1936) regard bicolor as a valid race. Further in connection with *Elachistocleis pearsei* which had apparently previously been regarded as a strict synonym for *ovalis*, he writes, "Mrs. Gaige of Michigan, wrote to me about it two years ago and our investigations seem to show that *pearsei* is a distinct northern form, range uncertain but probably Colombia. It reaches a much larger size, 44-47 mm., whereas *ovalis* never seems to exceed 37."

The following anatomical details are furnished by Parker: "Prevomer divided, the post-choanal portion lost; palatine absent. Clavicle and procoracoid present, much reduced, curved, resting on the mesial half of the coracoid: omosternum present; sternum cartilaginous. Vertebral column diplasiocoelous. Terminal phalanges simple.

Pupil round, tongue oval, entire and free behind. Two smooth, or slightly crenulate dermal ridges in front of the pharynx, the anterior shorter and curved. Digits free, tips not dilated."

MATERIAL AND TECHNIQUE.

A single specimen of *Elachistocleis ovalis* measuring 27 mm. from snout to vent was obtained from Dr. Lutz of the Instituto de Maguinhos, Rio de Janeiro, to whom we should like to express our thanks. It was eviscerated and the body cut off behind the pectoral girdle. After the lenses and the skin, except for the portion over the tympanum and around the external nares, were removed the specimen was decalcified for 10 days in HNO₃—alcohol (7.5 cc. HNO₃ in 100 cc. 60% alcohol). The acid was neutralised by placing the object in a 5% solution of Na₂SO₄ after which it was washed in tap water. The specimen was bulkstained in acid haemalum, and the sections cut at 16 μ , were counter-stained on the slides in aqueous eosin. The results were satisfactory.

The graphical reconstructions were made by projecting drawings obtained with the aid of the Panphot microscope on to graphed paper ruled in millimetres.

THE OLFACTORY CAPSULE.

The cartilaginous olfactory capsule which projects well beyond the lower jaw is continued past the premaxillaries as two crescent-shaped, medially convex prominences separated by a median vertical groove into which a ventral, anteriorly directed process of the septum nasi is produced. These three structures fuse posteriorly to form the septum and solum nasi.

the tectum and the anterior wall in the Gauppiian sense being absent (Text-fig. 1a and 1b and Text-fig. 2a and 2b). Similar conditions obtain in *Microhyla carolinensis* (Roux, in press). From the development of the Anuran ethmoidal region as investigated by Born (1876) and elaborated and amended by Gaupp (1892), it is evident that in the early stages the anterior portion of each nasal sac, containing the *cavum principale*, has its own cartilaginous inner wall which fuses secondarily with the septum, the latter developing from behind forwards. The space between the nasal sacs would correspond to the internasal space present in many Urodeles. Similar conditions have been described by Born for *Pelobates* (op. cit.) and clearly the retention of this larval feature in *Anura* should be regarded as neotenic.

(See Text-fig. 1, p. 216). The dorsal portion of the olfactory capsule has the appearance of having been pulled forwards and downwards with the result that the corresponding ventral portion has been pushed backwards. Rotation through an angle of almost 90° thus appears to have taken place. Consequently the inferior prenasal cartilage which normally occupies an anteroventral position is now situated posteroventrally; the fenestra nasobasalis has shifted from an anteroventral to a more posteroventral position and the alary cartilage with its attendant superior prenasal cartilage is situated anteroventrally. (Text-fig. 1a). It is, therefore, not surprising that the superior prenasal cartilage is now directed posteriorly instead of anteriorly as in *Rana*. If this interpretation is accepted, it will be found applicable to a number of *Anura* which have already been described, such as *Hemisus* (de Villiers, 1931a), *Breviceps* and *Pro-breviceps* (de Villiers 1931b, 1933), *Anhydrophryne* (de Villiers, 1931c), *Spelaeophryne* (de Vos, 1935), *Callulina* and *Microhyla* (Roux, in press).

(See Text-fig. 2, pp. 217/218). The posteriorly directed superior prenasal cartilage in *Elachistocleis* is in feeble synchondrotic continuity with a ventral process of the alary (Text-fig. 2c). It supports an anteriorly directed process of the premaxillary (Text-fig. 1a). The inferior prenasal cartilage is a minute structure free from the solum nasi. It supports the base of the anteriorly directed process of the premaxillary. The well-developed alary is connected to the solum by means of a slender cartilaginous stalk. (Text-fig. 2c). As in *Microhyla* (Roux, op. cit.) it supports the ventrolateral wall of the vestibulum. Since the anterior portion of the tectum is not present in *Elachistocleis*, the cartilago obliqua, consisting of very thin cartilage anteriorly, is syndesmotically attached to the lateral edge of the nasal. (Text-fig. 1b). This connection is soon lost and the cartilago obliqua shifts inwards behind the external nasal aperture

(Text-fig. 2c). On its way to the infundibulum the efferent duct of the glandula nasalis lateralis pierces this cartilage as in *Microhyla* (Roux, op. cit.). The planum terminale of the cartilago obliqua fuses with the posterior, much-calcified tip of the lamina inferior (Text-fig. 3c). The latter continues posteriorly as a medially directed spur, the processus lingularis, which is attached to the solum nasi. Ultimately this attachment is lost and the process ends freely in the plica isthmi some distance anterior to the processus maxillaris anterior. (Text-fig. 4a).

An irregularity occurs in *Elachistocleis* in the presence of a foramen frontale on the right hand side only, by means of which the ramus externus narium of the ophthalmic branch of the trigeminal nerve leaves the skull and passes into the connective tissue in the anterior nasal groove. (Text-fig. 2c). The ramus externus narium of the right hand side leaves the cavum interius by the fenestra nasobasalis. Similar conditions obtain in *Rana grayi* (C. A. du Toit. 1933) and *Microhyla carolinensis* (Roux, op. cit.). The fairly large ventrally situated fenestra nasobasalis therefore allows transmission of the ramus medialis narium as well as of the left ramus externus narium. (Text-figs. 1a and 2d). From his manuscript describing the African Microranids kindly lent me by Dr. C. A. du Toit, it appears that a large fenestra nasobasalis is a fairly common occurrence in these genera. This would indicate a neotenic condition in which the paraseptal portion of the solum nasi remains incompletely chondrified. A very small foramen is present anterior to each fenestra nasobasalis (Text-figs. 1a and 2c), but it is impossible to state whether the emerging nerve represents a branch of the ramus medialis narium or of the ramus externus narium. In a single specimen of *Rana* Gaupp (1904, p. 1") describes a separate foramen for the ramus communicans cum n. palatino of the ramus medialis, a condition possibly comparable with that obtaining in *Elachistocleis*.

According to Gaupp, the crista intermedia, in *Rana* arises dorsally to the fenestra nasobasalis from the anterior portion of the tectum nasi adjoining the septum. It then passes obliquely outwards and divides into two laminae, the lamina superior and the lamina inferior. The lamina superior continues posteriorly and laterally, whereas the lamina inferior fuses with the lateral wall of the nasal capsule, and posteriorly with the planum terminale of the cartilago obliqua. As has already been stated, the anterior wall and the tectum are absent in *Elachistocleis*, therefore a certain amount of modification in the relations of these structures is to be expected. Here the crista intermedia is attached to the septum and to the anterior and lateral edges of the solum. It is directly continuous with the lamina inferior, which is

also fused with the solum anteriorly, the lamina inferior only becoming distinguishable as such where the lamina superior is given off from the crista intermedia a short distance anterior to the cavum medium (Text-fig. 3a). The cavum medium in *Elachistocleis* occupies a markedly lateral position. The lamina superior to which the septomaxillary is attached forms its dorsal support, whereas the lamina inferior forms the medial and medioventral wall separating the cavum medium from the recessus medialis of the cavum inferius (Text-fig. 3b). The main ventral support of the cavum medium is achieved by the extension laterally of the fused solum and lamina inferior. This much-calcified extension first occurs at the level of the anterior tip of the lamina superior (Text-fig. 3a), and its lateral edge is curved dorsally so as to support the lateral portion of the cavum medium. (Text-fig. 3b) Posteriorly it forms a ventral and ventrolateral support for the anterior portion of the nasolacrimal duct (Text-fig. 3c), finally continuing in the plica isthmi as the processus lingularis. The interpretation of the complicated relations of the crista intermedia and its laminae has been considerably simplified as a result of Dr. C. A. du Toit's investigation on the Microranids already referred to. In many of these forms the anterior portion of the lamina inferior is fused to the solum. Posteriorly these structures separate to embrace the recessus lateralis of the cavum inferius. The cavum medium is always supported dorsally by the lamina superior and ventrally by the lamina inferior and since, in many of these forms as in *Elachistocleis*, the cavum medium extends further forwards than the recessus lateralis, the cartilage supporting it ventrally must represent the fused lamina inferior and solum which separate posteriorly on the appearance of the recessus lateralis. As a result of the comparison of juvenile and adult forms Dr. du Toit has come to the conclusion that this condition is neotenic.

(See Text-fig. 3, pp. 219/220). The crista intermedia with which the lamina superior is continuous separates from the septum posteriorly and allows passage of the ramus medialis narium from the cavum principale to the recessus medialis of the cavum inferius. (Text-fig. 3c). Posteriorly the crista is gradually reduced until finally the lamina superior alone with its attendant blade of the septomaxillary fuses with a slight, intensely calcified elevation of the solum. Similar conditions obtain in *Spelaeophryne* (de Vos, 1935) and *Microhyla* (Roux, op. cit.). This elevation persists as a distinct low ridge running parallel to the septum nasi with which the posterior end of the anteriorly directed process of the cartilaginous support of the eminentia olfactoria finally fuses.

The cartilaginous support of the eminentia olfactoria in *Elachistocleis* is a massive structure and occupies most of the space in the cavum principale. De Villiers (1933, p. 260) has expressed the opinion that these structures have been independently evolved in the *Bufoidea*, *Ranidae* and *Microhylidae* and are associated with adaptation to terrestrial life.

Helling (1938) also regards the elaboration of the eminentia olfactoria as a terrestrial specialisation but admits that additional factors may be responsible for its development. Ramaswami (1935a, p. 6), however, points out that although these conclusions are borne out by conditions in those *Microhylidae* investigated by him, the presence of a large eminentia olfactoria in two completely aquatic forms, *Rana hexadactyla* and *R. cyanophlyctis*, renders this explanation untenable. He, therefore, concludes that "the elevation of the eminentia has probably nothing to do with the terrestrial adaptations of the *Anura*. It may, however, be said that the structure increases in size purely in response to the sensory requirements of the individual." In his review of 1939 he reiterates this opinion. The eminentia olfactoria in *Elachistocleis* differs in certain respects from those which have previously been described. After the processus lingualis loses its connection with the solum, the latter itself is dorsally flexed and has the appearance of an inverted "U" with the vomer applied to its lateral arm (Text-fig. 4a). Tubules of the glandula intermaxillaris fill the cavity formed in this way. Anteriorly the ventral ends of the inverted "U" fuse where connection between the processus lingualis and the solum is established, thus forming a complete circle. The latter loses its connection with the solum and is continued forwards as a hollow cylindrical prolongation containing tubules of the glandula intermaxillaris and ending blindly anteriorly. A similar hollow prolongation has been described in *Proterorhynchus* (De Villiers, 1933) and *Speleophryne* (de Vos, 1935), but in these forms it communicates posteriorly with the lateral portion of the cavum principale whose undifferentiated epithelium is continued into the cylinder. Posteriorly the lateral arm of the inverted "U" shortens and the vomer forms its ventral continuation thus bridging the gap between the pars palatina of the maxillary and the lateral edge of the solum anterior to the choana. A large branch of the olfactory nerve passes along the dorsomedial surface of the curved eminentia, and its fibres are distributed in the high sensory epithelium of the eminentia. At the level of the choana a medial as well as a lateral thickening of the curved portion of the "U" occurs. (Text-fig. 4c and 4d). Consequently a depression is formed between the two thickenings along which the nerve is continued posteriorly.

The lateral thickening is more pronounced than the medial one, and it gives off a dorsal process which curves round and fuses with a similar process of the medial limb so that the nerve is now enclosed in a short tube. The connection is severed at the posterior end of the choana where the lateral, now much flattened limb of the eminentia support fuses with the planum antorbitale. The eminentia gradually disappears in the postchoanal region, the nerve eventually continuing alone along the floor of the posterior end of the cavum principale and finally entering the cranial cavity in the orbital region.

THE NASAL CAVITIES.

(See Text-fig. 4, pp. 221/222). The nasal cavities of *Elachistocleis* are characterised by the relatively large cavum principale as compared with the extremely small accessory cavities. The recessus alaris and the recessus sacciformis are absent. The apertura nasalis externa is situated dorso-laterally near the tip of the snout and is guarded externally by a dorsal and a ventral fold of skin. Approximation of these folds would ensure a more effective closure of the nostril: a significant modification in a fossorial form (Text-fig. 2b). Behind the external naris these folds fuse forming a short canal representing the niche-like recess of the vestibulum (Text-figs. 2b, 2c and 2d).

The vestibulum leads directly into the infundibulum and the cavum principale, the plica terminalis separating the latter two cavities being entirely absent as in *Breviceps mossambicus*, *Callula pulchra* and *Microhyla* sp. (Helling 1938), as well as in *Arthroleptides* (C. A. du Toit, 1938). It would appear, therefore, that this condition is characteristic of the majority of the *Microhylidae*. Roux, however, describes a poorly developed plica terminalis in *Microhyla carolinensis* (op. cit.). The plica obliqua is a small, cushion-shaped structure functionally replaced by the cartilago obliqua (Text-fig. 2c and 2d). As in *Crinia* (C. A. du Toit, 1934), *Spelaeophryne* (de Vos, 1935) and *M. carolinensis* (Roux, op. cit.), the alary supports the entire lateral wall of the apertura externa, disappearing after the closure of the latter (Text-fig. 2b, 2c and 2d). Thus here, too, the first Gauppiian "Wulst" occurs together with the alary cartilage, being supported by its dorsolateral edge, instead of functionally replacing the alary in the posterior region of the apertura externa (Text-fig. 2c). The "Wulst," however, still retains its function of serving as a soft pad against which the plica obliqua presses in order to shut off the posterior niche-like recess of the vestibulum from the cavum principale during certain respiratory movements. In *Elachistocleis* the medial boundary of the vestibular recess

is formed by the "Wulst" instead of by the plica obliqua as in *Rana*, the portion internal to the "Wulst" representing the infundibulum (Text-fig. 2b). The finger-shaped "Wulst" is entirely absent. The validity of Gaupp's description of a complicated structure, the recessus sacciformis, in *Rana* has given rise to a good deal of controversy. In *Elachistocleis* the infundibulum forms a distinct dorsolaterally directed recess behind the niched portion of the vestibulum. Fibres of the *musculus lateralis narium* are inserted into its dorsal and dorsolateral walls and it is bounded mediadorsally by the *cartilago obliqua* (Text-fig. 2d). Posteriorly it assumes a more horizontal position and is finally directed lateroventrally.

The posterior portion is encased dorsally, laterally and ventrally by the horseshoe-shaped septomaxillary and bounded dorsomedially by the *musculus medialis narium* (Text-fig 3a and 3b).

The infundibular recess lies parallel and dorsal to the cavum medium. Behind the level at which communication between the two cavities is established, the infundibular recess and the lateral portion of the cavum medium are severed from their medial portions by the fusion of the *planum terminale* of the *cartilago obliqua* with the posterior tip of the *lamina inferior*. The wall separating these isolated cavities disappears and together they form a common opening to the nasolacrimal duct (Text-fig. 3c).

De Villiers (1931a and c) homologises the infundibular recess in *Hemisus* and *Cacosternum* with the recessus sacciformis, although he admits that its relations to the adjacent cavities differ from those described by Gaupp for *Rana*. From the text-figures it seems very probable that in these forms, too, the infundibular recess, together with the lateral portion of the cavum medium form the opening of the nasolacrimal duct. In his description of *Rhomboophryne* (de Villiers, 1934a) he states: "Der Ductus nasolacrimalis mündet in eine aus Verschmelzung des Cavum medium und Infundibulum entstandene Kammer," and a similar even more exhaustive description is given for *Ascaphus* (de Villiers, 1934b). Thus his opinion regarding the fate of the infundibular recess has apparently been revised. The problem concerning the recessus sacciformis and the infundibular limb or recess is solved by C. A. du Toit's work on *Crinia* (1934) in which both cavities occur. Although it establishes no direct connection with the cavum medium, the presence of a genuine recessus sacciformis in *Crinia* is irrefutably proved, owing to the insertion into its lateral wall of a number of fibres of the *m. lateralis narium*, and owing to its relation to the niche-like recess of the vestibulum, the two cavities being completely separated posteriorly from the

other nasal cavities. An interesting deviation from the usual type of communication of the nasolacrimal duct with the cavum medium is encountered in *Crinia*. In this form the duct enters the dorsal part of the horizontal limb of the infundibulum at the level at which the infundibulum communicates with the cavum medium. It would be premature, at this stage, to speculate on the morphological significance of this fact. Ramaswami (1935b) describes a combined opening in the Pelobatid *Megophrys major* and a normal communication between the nasolacrimal duct and the cavum medium in *Scaphiopus*.

Helling (1938) introduces an entirely new nomenclature for the anterior nasal region. According to him there is a tendency in Anurans to the formation of an isolated nasal opening for the nasolacrimal duct by means of which the liquid is conveyed directly to the exterior without coming into contact with the olfactory cavity, especially the cavum principale. In all the *Discoglossidae* as well as in *Acris gryllus*, *Pseudacris nigrita* and *Phrynobatrachus* sp., separation is effected by the fusion of the plica obliqua with the floor of the cavum principale so that the medial olfactory region is independent of the lateral portion along which the secretion is conducted. In forms in which the plica obliqua is less well-developed, the inclusion of a "Schaltstück" between the cavum medium and the "Vorraum" (Helling) comprising "laterale und mediale Spalträume," effects the necessary separation. The "medialer Spaltraum" corresponds to the infundibulum, and the "Schaltstück" is a vestigium. After communication between the infundibulum and the cavum medium is established, the "Schaltstück" and the lateral portion of the cavum medium are separated from the remaining nasal cavities, and together they form the opening of the nasolacrimal duct. Thus the infundibular recess in *Elachistocleis* would correspond to Helling's "lateraler Spalträum" and "Schaltstück" anteriorly, and with the "Schaltstück" alone posteriorly. This group includes most of the *Bufo*nidae, *Pelobates*, the *Hylidae*, *Microhylidae*, *Brachycephalidae*, certain *Rhacophoridae*, and a few other forms. In the third group comprising a number of *Ranidae*, *Leptodactylus*, *Leptopelis*, *Rhacophorus reinwardti*, *Nototrema* and *Phylomedusa*, the nasolacrimal duct opens into the cavum medium only, although Helling insists that vestiges of the "Schaltstück" are still present connecting the duct to the exterior. He maintains that the infundibulum and "Schaltstück" are distinct structures owing to the difference in their epithelial linings. In *Elachistocleis* that part of the infundibulum corresponding to the "Schaltstück" is lined with low cubical epithelium.

whereas the medial portion communicating with the cavum principale consists of high cylindrical epithelium. The fact that there is a gradual transition from the high cylindrical epithelium of the cavum principale to the low cubical epithelium of the infundibular limb invalidates Helling's distinction. Topographically, his method of description may simplify matters to a certain extent especially in the second group including the *Microhylidae*, but his distinctions are obviously artificial when applied to the third group in which the cavum medium alone communicates with the nasolacrimal duct.

The recessus medialis of the cavum inferius or the so-called Jacobson's organ extends further forward than the recessus lateralis. It is an oval structure lined with high sensory epithelium and completely surrounded anteriorly by tubules of the glandula nasalis medialis (Text-fig. 3a and 3b). Posteriorly the cavity becomes more elliptical in shape and is invaded posterolaterally by a zone of undifferentiated epithelium (Text-fig. 3c) dividing it into a medial and lateral canal containing sensory epithelium. The zone of undifferentiated epithelium expands further backwards to form the recessus lateralis of the cavum inferius. The duct of the glandula nasalis medialis opens into the dorsal wall of the zone of undifferentiated epithelium. There is no "caudaler Blindsack" of the recessus medialis, the latter disappearing very soon after it loses its connection with the recessus lateralis. The recessus lateralis is a comparatively small cavity communicating anteriorly with the cavum principale by means of the cavum medium and the medial portion of the infundibulum. Posteriorly it is separated from the cavum principale by the plica isthmi (Text-fig. 4a 4b and 4c), finally disappearing along the roof of the buccal cavity as the sulcus maxillopalatinus.

NASAL AND OROPHARYNGEAL GLANDS.

The greater mass of the glandula nasalis medialis is situated anteriorly, its tubules completely surrounding the anterior portion of the recessus medialis and continuing past the fenestra nasobasalis (Text-fig. 2d) to the region in which the crista intermedia fuses with the anterior portion of the solum. Posteriorly it rapidly decreases in size, its tubules continuing to the level at which the anteriorly directed process of the eminentia olfactoria arises from the solum. The glandula nasalis lateralis is well-developed and situated some distance posteriorly to the apertura nasalis externa. Its anteriorly directed efferent duct opens into the cavum principale (Text-fig. 2c) after piercing the cartilago obliqua, as has already been described. The gland is completely surrounded anteriorly by the musculus lateralis narium whose

fibres extend to the anterolateral tip of the cartilago obliqua. It is situated dorsally to the ductus nasolacrimalis as in *Microhyla carolinensis* (Roux, op. cit.) and laterally to the planum terminale (Text-fig. 3c). After the formation of the processus lingularis, the posterior portion of the gland is supported by it and is continued in the plica isthmi to the point of origin of the eminentia olfactoria from the solum. It thus extends as far posteriorly as the glandula nasalis medialis. Besides these glands, another of unknown significance and function occurs in the nasal capsule immediately in front of the cavum medium. Its anterior portion is situated dorsolaterally to the crista intermedia and medioventrally to the infundibular recess (Text-fig. 2c). Posteriorly it lies between the lamina superior and the lamina inferior and is finally replaced by the cavum medium which occupies this space. A similar structure has been described for *Spelaeophryne* (de Vos, 1935) and *Microhyla carolinensis* (Roux, op. cit.). Helling (1938) notes its presence in *Callula*, *Microhyla* and *Breviceps* and suggests the rather appropriate name "glandula nasalis infundibularis" for it (Text-fig. 2d).

The theory was first put forward by Wiedersheim that the secretion of the glandula intermaxillaris renders the tongue of the frog adhesive for the purpose of catching its prey. This gland is very well-developed in *Elachistocleis*, a form which lives mainly on termites (Lutz, 1927). As in *Bufo quercicus*, *Microhyla* sp., *Hyla pickeringii* and *Rhinoderma* (Müller, 1932), as well as in *M. carolinensis* (Roux, op. cit.), it does not reach the cavum praenasale, and in consequence of its poor development in the anterior subnasal region it does not penetrate the fenestra nasobasalis. Its anterior tip lies between the premaxillaries (Text-fig. 3c), and in the prechoanal region it forms a dense mass filling the space beneath the inverted "U" of the cartilaginous support of the eminentia olfactoria (Text-fig. 4a). Some of its tubules are prolonged into the anteriorly directed process of this support. Posteriorly the tubules surround the anterior walls of the prechoanal sacs into which many of them open. The dorsal portion of the gland is continued into the choanal region as two distinct strands underlying the cartilaginous elevation of each eminentia (Text-fig. 4b), and shortly after communication between the prechoanal sacs and the buccal cavity is established, a large main duct consisting of the union of several smaller ducts from the dorsal strand, enters the prechoanal sac (Text-fig. 4c). Posterior to this, there are a few isolated openings and the gland is finally replaced by tubules of the medial portion of the "Rachendrüse" which are prolonged anteriorly along the medial choanal edge.

Similar conditions obtain in *Microhyla fissipes* and

Engystoma carolinense (syn. *Microhyla carolinensis*) (Müller, 1932), as well as in *M. pulcra* (Cohn, 1910, quoted from Müller). On page 146 Müller writes: "Diese letzten Schläuche," i.e. of the glandula intermaxillaris, "grenzen ganz eng an den am medialen Choanenrand sich nach vorn schiebenden Teil der Rachendrüse an. Lediglich eine hellere Färbung und Interzellulärspalten, die an allen Schläuchen der Rachendrüse aufgetreten waren, lieszen eine Trennung der Beiden Drüsen durchführen." According to Roux (op. cit.), the medial portion of the "Rachendrüse" is absent in *M. carolinensis*, but a re-examination of the sections reveals that conditions here correspond exactly to those described by Müller. The more deeply staining epithelium of the "Rachendrüse" with its distinct basal nuclei is clearly distinguishable from the lighter epithelium of the glandula intermaxillaris where the tubules intermingle. This fact greatly facilitated the interpretation of conditions obtaining in *Elachistocleis* in which the staining method rendered histological distinction impossible. The lateral portion of the Rachendrüse in *Elachistocleis* is continued forward in the plica isthmi to the anterior level of the pre-choanal sacs. At intervals its tubules communicate with the cavum principale. Posterior to the choanae the medial and lateral portions of the gland unite, and this mass extends along the palatal surface beyond the planum antorbitale into the orbital region, being separated from the Harderian gland by muscular and connective tissue.

THE CHOANAE AND THEIR RELATIONS TO THE OROPHARYNGEAL CAVITY.

Two prechoanal sacs are present in *Elachistocleis*. They first appear as thickened patches of epithelium ventral to each eminentia olfactoria about 0.128 mm. anterior to the choanae. Posteriorly they form two cavities separated by a strip of epithelium (Text-fig. 4b) which disappears at the anterior level of the choanae, so that the latter open into a single horizontal cavity (Text-fig. 4c). This in turn communicates with the buccal cavity about four sections further back (Text-fig. 4d). With the reduction of the palatal folds behind the prechoanal sacs the choanae open directly into the buccal cavity. Boulenger (1882) mentions the presence of cutaneous palatal folds in *Phrynomerus* but the true nature of these folds was first elucidated by de Villiers for *Phrynomerus* (1930), who attributes the formation of the prechoanal sacs to the fusion of Gaupp's "Gaumenleiste" or palatal folds anterior to the choanae. He considers these sacs to be possible homologues of the buccal division of Jacobson's organ in Anamniotes; he subsequently described similar structures in *Cacosternum* (1931d), *Anhydrophryne*

(1931c), *Breviceps* and *Probreviceps* (1931b, 1933), *Rhomboophryne* (1934a) and *Ascaphus* (1934b). C. A. du Toit (1930) describes a dorsal and a ventral prechoanal sac in *Heleophryne*. The dorsal one is formed by the fusion of the "Gaumenleiste" and is homologous with the prechoanal sacs described by de Villiers. I agree with Roux (op. cit.) that the ventral cavity cannot be regarded as a prechoanal sac in the true sense of the word, since an examination of the sections revealed that its floor is formed by the fusion of Gaupp's "Oberlippenfalte" over the fossa subrostralis media. Besides these forms true prechoanal sacs have been described in *Phrynobatrachus* (G. P. du Toit, 1933) and *Spelaeophryne* (de Vos, 1935). Ramaswami mentions them in a number of Indian forms including *Cacopus*, *Kaloula* and *Microhyla* (1932a), *Megophrys major* (1935b), *Kaloula Gray* and *Phrynella Boulenger* (1936) as well as *Uperodon systema* (1939).

THE BURSA ANGULARIS ORIS OR "MUNDWINKELDRÜSE."

A well-developed bursa angularis oris or "Mundwinkel-drüse" is present in *Elachistocleis*. Its anterior portion consists of a mass of loosely packed lymphoid tissue which first appears near the posterior end of the eye, being situated ventrally to it and dorsolaterally to the arcus subocularis immediately underneath the skin. Posteriorly it acquires a vertical elliptical lumen lined by ciliated epithelium. This structure is accompanied medially by a large bloodvessel and by the ramus supramaxillaris of the trigeminal nerve which is situated ventrally between the bloodvessel and the bursa angularis oris. Posteriorly the nerve passes dorsally between the two and comes to lie on the dorsomedial surface of the bursa, dorsal to the bloodvessel. At the level at which the maxilla loses its connection with the pterygoid process, a strip of connective tissue extends from the tip of this bone, completely encapsulating the bursa posteriorly and separating it from the nerve. In this region its lateral wall is infiltrated by an aggregation of alveolar lip glands which project into the lumen. The epithelium adjacent to the lip glands loses its cilia and assumes the stratified appearance of the outer skin. This stratified epithelium extends round the medio-ventral wall of the lumen whereas the dorsal ciliated portion of the epithelium is replaced by high cylindrical epithelium resembling buccal epithelium.

In this region lymphoid tissue disappears. After the fusion of the upper and lower lips, the ventral stratified portion becomes confluent with a groove in the angle of the mouth which is continued posteriorly between the pterygoid process and Meckel's cartilage into the anterior otic region where it disappears.

In 1931 Fuchs described a structure, the ductus angularis oris in the Chelonians *Podocnemis expansa*, *Emys europea* and *Chelone imbricata*. He expressed the opinion that a possible homology might exist between this organ and a similar structure, the bursa angularis oris, situated between the maxilla and the processus pterygoideus in the Anurans *Dendrobates tinctorius*, *Discoglossus pictus*, *Bombinator igneus* and *B. pachypus*. In the same year de Villiers described a similar structure in *Anhydrophryne* which he called the "Mundwinkeldrüse." However, since the name was previously given to a gland situated externally to the jaws in birds (Gaupp, 1888, p. 436), Fuchs's nomenclature has been accepted in preference to de Villiers's term "Mundwinkeldrüse" on the grounds that the homology of the "Mundwinkeldrüse" of birds with that of Anurans was far from certain owing to the difference in the topographical relations of the structures (C. A. du Toit, 1934).

In this connection it is interesting to note that in a large number of Anurans, the skulls of which have been described since the appearance of the work of Fuchs and de Villiers, the anterior portion of the structure in almost all cases is situated between the maxilla and the pterygoid process. In *Probreviceps* (de Villiers, 1933) and *Spelaeophryne* (de Vos, 1935) a slight deviation from the usual type is encountered, the structure being situated behind the posterior end of the maxilla. It is therefore not bounded by this bone laterally. Müller (1932, p. 168) described a "Mundwinkeldrüse" in *Rhinophrynyus*, the ducts of which open into the "Mundwinkel." The anterior portion of the gland extends forwards laterally to Meckel's cartilage and its investing bones, and behind the "Mundwinkel" it retains its position immediately underneath the skin, external to the processus pterygoideus and Meckel's cartilage. No similar gland has been described in other Anura and on this account Müller suggests a possible relation between it and the lip glands of snakes, birds and certain tortoises. The anterior portion of the bursa in *Elachistocleis* occurs along the upper jaw, externally to the maxilla, thus also corresponding topographically to the "Mundwinkeldrüse" in birds.

Fahrenholz (1937) does not exclude the possibility of an homology existing between the "Mundwinkeldrüse" of birds and the ductus angularis oris of tortoises. Although it is impossible at the present stage to affirm a definite homology of the structures present in Anurans, Chelonians and birds, it appears very likely that future research will reveal that the relations of the structures in all three groups to the "Mundwinkel," and not their topographical disposition will prove to be of phylogenetic significance.

MEMBRANE BONES OF THE NASAL REGION.

The nasals in *Elachistocleis* as in *Microhyla* (Roux, op cit.) are enormous bones covering almost the entire nasal capsule dorsally and dorsoventrally, thus functionally replacing the tectum anteriorly. They are continued to the tip of the snout as two dorsally convex structures whose medial thickened portions curve downwards into the groove between the two cartilaginous anterior prominences of the nasal capsule. The medial edges of the bones are closely approximated, being separated by a very narrow strip of connective tissue. Owing to the almost complete absence of the tectum anteriorly, the cartilago obliqua receives its support from the nasal, its anterodorsal tip being attached to it by a strand of connective tissue. The lateral portions of the cartilaginous anterior prominences, the anterior portion of the cartilago obliqua and most of the cartilago alaris project beyond the lateral edge of the nasal, but posterior to this almost the entire nasal capsule is roofed over by the bone. At the anterior end of the cavum medium, the nasal curves down towards the septomaxillary, protecting the musculus lateralis narium and the glandula nasalis lateralis dorsally and laterally (Text-fig. 3b).

Strong connective tissue connects the lateral edge of the nasal with the lateral extension of the fused solum and lamina inferior. This is particularly noticeable where the infundibulum and the cavum medium are in communication. After the formation of the processus lingularis, the nasal approaches very close to the latter, being situated dorso-medially to the nasolacrimal duct. It is separated from the pars facialis of the maxillary by the curved portion of the processus lingularis where the latter is attached to the solum. After the disappearance of the processus lingularis the edges of the nasal and pars facialis are directly apposed, being separated by connective tissue, so that a continuous dorsal and lateral bony shield is formed between the posterior end of the processus lingularis and the processus maxillaris anterior. As soon as the ossified portion of the tectum appears in section, the dorsal portion of the nasal disappears, its lateral portion being continued as a splint-like process overlapping the planum antorbitale and finally disappearing before the closure of the choanae.

Owing to the peculiar modification of the nasal capsule the entire premaxillary is situated ventral to the solum, its anterior tip being supported by the posteriorly directed superior prenasal cartilage, and its base by the delicate inferior prenasal cartilage (Text-figs. 1a and 2c and 2d). Were the portion between the inferior and superior prenasal cartilages rotated anterodorsally, it would correspond to the

Ranid pars facialis. The pars dentalis is present but is poorly developed, as is the pars palatina. In the region of the fossa subrostral media the partes palatinae of the premaxillaries are fairly closely approximated, but they diverge posteriorly, disappearing near the posterior end of the processus lingularis without each dividing into two palatal squames. Since the premaxillary is situated ventral to the nasal capsule, the maxillary occupies a rather posterior position. It leaves the greater portion of the lateral extension of the fused solum and lamina inferior exposed to the palatal surface (Text-figs. 1a and 3b and 3c), a condition reminiscent of that obtaining in *Phrynomerus* (de Villiers, 1930), *Breviceps* (de Villiers, 1931b), *Probreviceps* (de Villiers, 1933), *Spelaeophryne* (de Vos, 1935) and *Microhyla carolinensis* (Roux, op. cit.) in which the anterior part of the crista subnasalis is not covered by the maxillary. The maxillary is edentulous and consists of the usual palatal, facial and dental parts. After the disappearance of the processus lingularis posteriorly, the maxillary alone forms the entire ventrolateral support of the nasal capsules (Text-fig. 4b and 4c) since the processus maxillaris anterior does not extend nearly as far forward as it does in *Microhyla carolinensis* (Roux, op. cit.).

As in the case of *M. carolinensis*, a processus frontalis is absent. The pars facialis of the maxillary is almost contiguous with the lateral edge of the nasal until the latter disappears in the anterior region of the planum antorbitale. The place of the nasal is then immediately occupied by the pterygoid which, therefore extends further forward than is normally the case.

The septomaxillary in *Elachistocleis* very closely resembles that of *Microhyla carolinensis* (Roux, op. cit.), but since the infundibulum in *Elachistocleis* does not possess a distinct anterior ventral recess, which gradually becomes more ventrolaterally directed, the rotation of the septo-maxillary is not as marked anteriorly as in *Microhyla* (Roux, op. cit.). The anterior portion of the septomaxillary is horse-shoe-shaped (Text-fig. 3a and 3b), forming a dorsal, lateral and ventral support for the infundibulum, and first appearing in section where the "glandula nasalis infundibularis" communicates with the infundibulum. The dorsal horizontal limb of the bone is situated ventrally to the glandula nasalis lateralis as in *Microhyla* (Roux, op. cit.), whereas the ventral horizontal limb, which is the first to appear in section, encases the lateral edge of the lamina superior and forms the osseous wall separating the infundibulum from the cavum medium (Text-fig. 3a and 3b). The relation between the bone and the cartilage is so intimate

that all traces of separating connective tissue have disappeared.

A few sections anterior to the level at which communication between the infundibulum and the cavum medium is established the ventral horizontal limb is separated into a smaller medial portion encasing the lamina superior and a larger lateral portion which is continuous with the dorsal horizontal limb. The dorsal horizontal limb now extends further medially and becomes so closely applied to the ventral edge of the planum terminale of the cartilago obliqua that here, too, all traces of connective tissue between the two structures have disappeared. The lateral curved portion of the bone with which the lateral portion of the ventral limb is continuous, is severed from the dorsal limb and disappears. The lateral portion of the dorsal limb is also reduced, and as the planum terminale approximates to the posterior end of the lamina inferior, only the medial portion of the bone surrounding the tip of the planum terminale persists. After fusion of the latter with the lamina inferior, a smaller median and a larger lateral blade of the septomaxillary adhere to the planum terminale for a short distance before disappearing (Text-fig. 3c). All that now remains of the septomaxillary is the median portion of the ventral limb which encloses the lamina superior. It disappears shortly after connection of the lamina superior with the solum is established, and therefore does not come into contact with the vomer as in the case of *M. carolinensis* (Roux, op. cit.).

The vomers (prevomers) are well-developed and edentulous (Text-fig. 1a). Each first appears as a vertically directed blade applied to the ventrolateral side of the cartilaginous support of the eminentia olfactoria (Text-fig. 4a). With the reduction of the solum and the processus lingularis posteriorly, it forms a ventrolaterally directed continuation of the lateral limb of the inverted "U"-shaped cartilage, supporting the eminentia olfactoria and bounding the anterior wall of the choana (Text-fig. 1a). Immediately before the choana opens into the prechoanal sacs, the vomer divides into a medial blade attached to the solum and prolonged intranasally, and a lateral blade forming the ventrolateral support of the anterior region of the choana (Text-fig. 4b).

The palatines are entirely absent in *Elachistocleis*. Similar conditions obtain in the *Brevicipitinae*. *Brevicen-* (de Villiers, 1931b). *Probreviceps* (de Villiers, 1933), *Spelaephryne* (de Vos, 1935) and *Callulina* (Roux, in press). In addition their absence is noted in *Microhyla* (H. W. Parker, 1928, quoted from Ramaswami, 1935a), *Hemisus* (de Villiers, 1931a), *Ascarphus* (de Villiers, 1934b), *Scaphiopus* and *Megophrys major* (Ramaswami, 1935b), *Phrynellula pulchra* (Ramaswami, 1939) and *M. carolinensis* (Roux, op. cit.).

In discussing the relationships of the Malagasy *Microhylidae* Noble and Parker (1926) note a tendency in these forms to a division of the vomer (prevomer) into an anterior and posterior half. "The posterior portion usually overlies the palatines and has been confused with these latter bones." According to Parker (1931) considerable variation is shown in the vomero-palatine region of the *Microhylidae*. In the more primitive African, Malagasy and Indo-Papuan genera "the vomerine and palatine bones are ankylosed or completely fused to form a horse-shoe-shaped bone which almost entirely surrounds the choana. But both in Madagascar and in the Indo-Malayan region a series of stages can be traced showing the division of the vomer into two pieces, its separation from the palatine and the ultimate complete loss of the post-choanal portion." The text-figures show a corresponding reduction in the size of the palatine. A vomero-palatine is described by de Villiers in *Phrynomerus* (1930), which he regards as a possible link between this form and the toothed Malagasy Microhylids. A vomero-palatine is also present in *Liopelma* (Wagner, 1934a).

In connection with the absence of the palatine the ossification of the planum antorbitale in *Elachistocleis*, *M. carolinensis* (Roux, op. cit.), *Scaphiopus* and *Megophrys major* (Ramaswami, 1935b) is interesting, although in the *Brevicipitinae* which also lack the palatine, no such ossification occurs.

THE SPHENETHMOID REGION.

With the reduction of the nasals posteriorly, the tectum gradually extends laterally and fuses with the planum antorbitale in the posterior region of the choana (Text-fig. 1b). The sphenethmoid or "os-en-ceinture" commences as an ossification of the dorsolateral portion of the tectum. This ossification extends into the medial portion of the intensely calcified planum antorbitale, and in the post-choanal region, the entire pars plana of the planum antorbitale as well as the lateral portion of the solum is ossified. The planum triangulare which merges posteriorly into the processus maxillaris posterior, the medial portion of the solum and the entire septum remain cartilaginous. The "os-en-ceinture" is thus distinctly paired throughout its length as in *Phrynomerus* (de Villiers, 1930), *Hyperolius* (G. P. du Toit, 1932), *Crinia* (C. A. du Toit, 1934) and *Microhyla carolinensis* (Roux, op. cit.).

The foramen orbitonasale pierces the "os-en-ceinture" dorsolaterally. Since the posterior end of the cavum principale is prolonged underneath the cranial cavity, the foramen olfactorium, which is bounded laterally by the "os-en-ceinture" is situated in its floor. It follows, therefore, that

the posterior end of the cavum principale is supported dorso-laterally, laterally and ventrolaterally by the "os-en-ceinture" as in *Microhyla carolinensis* (Roux, op. cit.).

THE ORBITAL, OTIC AND OCCIPITAL REGIONS.

The side walls of the cranial cavity in the orbital region are mainly membranous as in *Crinia* (C. A. du Toit, 1934), *Callulina* and *Microhyla* (Roux, op. cit.). The floor of the cranial cavity is cartilaginous throughout its entire length and the only dorsal cartilaginous elements in the orbital region are the thin *taeniae tecti marginales* which merge anteriorly into the "os-en-ceinture" and posteriorly into the exoccipitals. These latter bones invade the posteroventral edges of the *taeniae tecti marginales*. Similar conditions obtain in *M. carolinensis* (Roux, op. cit.). No *taenia tecti transversalis* is present, a condition very common in the South African *Anura*, but a prominent *taenia tecti medialis* projects freely into the large *fenestra* probably formed by the confluence of the parietal and frontal *fenestrae*.

According to Ramaswami (1940) the *pila antotica* is not developed in the *Microhyliidae* investigated by him, and since de Beer (1937, p. 204) has shown that in *Rana* the *taenia tecti transversalis* originates from a median unpaired chondrification which interconnects the two *pilae antoticae*, and with which the *taenia tecti medialis* fuses, the above suggestion concerning the origin of the dorsal *fenestra*, although based on adult anatomy only, is not altogether unsubstantiated. The theory of some authors that the *taenia tecti transversalis*, when lacking, has been incorporated in the *tectum synoticum*, leaving the *taenia tecti medialis*, where present, to project into the *fenestra* therefore appears unlikely.

The frontoparietals are large bones closely approximated and separated by a narrow strip of connective tissue, a condition resembling that obtaining in *Microhyla*, *Kaloula* and *Cacopus* (Ramaswami, 1932a) and *M. carolinensis* (Roux, op. cit.) and differing markedly from that present in the South African *Brevicipitinae*, where these bones are separated by a wide tract of connective tissue. Anteriorly the frontoparietals rest on the "os-en-ceinture" and on the medial cartilaginous *tectum*, being separated from these by connective tissue. Posteriorly they show the same relations to the *taenia tecti medialis* and the *tectum synoticum*. The *parasphenoid* is typically forked anteriorly, its tip supporting the posterior ventral remnants of the "os-en-ceinture." The exoccipital extends into the orbital region as far as the optic foramen. The latter is, however, entirely surrounded by connective tissue as in *Crinia* (C. A. du Toit, 1934), *Rhacophorus* and *Philautus* (Ramaswami, 1934), *M. carolinensis*.

nensis and *Callulina* (Roux, op. cit.). As in these forms, with the exception of *Rhacophorus* and *Philautus*, the trochlear foramen is situated anterodorsally to the optic foramen. In *Elachistocleis* this is bounded dorsally by the prootic bone and ventrally by connective tissue. A cartilaginous sclera is present. The foramen prooticum is a large vacuity in the prootic (Text-fig. 7a), which, besides allowing transmission of the usual nerves and of the *vena capititis lateralis*, also permits the passage of the oculomotor nerve and of the *arteria carotis cerebralis* through its anteroventral corner.

In the otico-occipital region the extensive prootic and exoccipital ossifications are separated dorsomedially by the much-calcified *cartilago prootico-occipitalis*. This cartilage gradually replaces the prootic bone laterally, being prolonged into the *crista parotica* and the lateral cartilage ledge, the relations of which are described in connection with the suspensorial region. It also extends into the medial walls of the auditory capsule. The foramen *endolymphaticum* which penetrates the *cartilago prootico-occipitalis* is widely separated from the foramen *acusticum anterius*, the latter being situated in the cartilage a good distance posteriorly and rather more ventrally to it. The foramen *acusticum posterius* is situated closely behind the foramen *acusticum anterius* on the border between the *cartilago prootico-occipitalis* and the exoccipital. It is surrounded by the exoccipital except for its anterior and the greater part of its ventral walls which consist of cartilage.

The foramen *ovale* is large and ovoid with cartilaginous anterior and ventral edges. Its dorsal rim to which the operculum is attached, however, is formed by the anterior perichondrally ossified portion of the exoccipital. Posteriorly the operculum loses its connection with the auditory capsule and disappears before the posterior bony limit of the foramen is reached. The posterior and posteroventral walls of the foramen *ovale* are, therefore, entirely osseous.

Upon the disappearance of the exoccipitals, the anterior portions of which are covered by the frontoparietals, the latter are reduced to mere strips. Posteriorly the *tectum synoticum* is deeply notched so that a fairly large portion of the cranial cavity is roofed over by connective tissue as in *Cacosternum* (de Villiers, 1931d), *Crinia* (C. A. du Toit, 1934) and *M. carolinensis* (Roux, op. cit.). The exoccipital condyles are prominent osseous structures with cartilaginous tips.

The parasphenoid is typically dagger-shaped, the lateral wings supporting the auditory capsule and its lateral cartilage ledge being posterolaterally directed (Text-fig. 5a and 5b). The medial portion of this bone persists further posteriorly

than the lateral portions, and it accompanies the planum basale which projects freely backwards beneath the foramen magnum to near its posterior tip.

(See Text-fig. 5, p. 223). The foramen perilymphaticum superius opens into the spatium meningeale in the cranial cavity anterior to the closure of the foramen ovale (Text-fig. 5a). Immediately after the closure of this foramen, the foramen perilymphaticum inferius also communicates with the cranial cavity a short distance anterior to the jugular foramen. This is apparently a neotenic feature (cp. Gaupp, 1904). The dorsolaterally facing jugular foramen is situated in the exoccipital. The posterior portion of this foramen is more laterally disposed, and the condyloid fossa into which the glossopharyngeal and vagus nerves and the saccus perilymphaticus open, is well-defined. It is supported ventrolaterally by the posterior tip of the lateral cartilage ledge of the auditory capsule which becomes osseous immediately anterior to its disappearance. A similar dorsal position of the jugular foramen has been described in *Hemisus* (de Villiers, 1931a) and *Spelaeophryne* (de Vos, 1935). Its position in the case of *Elachistocleis* can probably be ascribed to the peculiar modification of the auditory capsule by the lateral cartilage ledge which has rotated the whole complex round dorsally.

THE SOUND CONDUCTING APPARATUS.

The sound conducting apparatus conforms to the general Microhylid type. A well-developed sickle-shaped annulus tympanicus is present with the discontinuity facing upwards and backwards. At no point does it come into contact with the cartilaginous auditory capsule, the paraquadrate effecting the necessary separation throughout. A similar incomplete annulus has been described for *Phrynomerus*, *Breviceps*, *Cucosternum* (de Villiers, 1930, 1931b and d), *Eleophryne* (C. A. du Toit, 1930), *Crinia* (C. A. du Toit, 1933), *Arthro-leptides* (C. A. du Toit, 1938), *Glyphoglossus* (Ramaswami, 1932b), *Cacopus*, *Kaloula* and *Microhyla* (Ramaswami, 1932a), and *M. carolinensis* (Roux, op. cit.). Ramaswami regards the presence of an incomplete annulus as one of the distinguishing features of the "Engystomatidae" (*Microhylidæ* Parker, 1934). The shape of the annulus appears to be of little taxonomic value, however, since it varies even in members of the same sub-family. The *Brevicipitinae* *Spelaeophryne* (de Vos, 1935) and *Callulina* (Roux, op. cit.), for example, possess a complete annulus whereas in *Breviceps* (de Villiers, 1931b), it is incomplete.

The pars externa plectri is embedded in the tympanic membrane and is enlarged to form an extraplectral (Text-fig. 7a, 7b and 7c). A pars ascendens partis externae plectri is

absent as in most *Microhylidae*. The pars externa plectri is less specialised in the *Brevicipitinae* than in most other *Microhylidae*, being simple and rod-like in *Spelaeophryne* (de Vos, 1935) and *Callulina* (Roux, op. cit.). It is larger in *Breviceps*, but according to de Villiers (1931b), does not warrant the name extraplectral. In *Probreviceps* (de Villiers, 1933) judging from the figures, it is even larger. Most *Microhylinae* including *Cacopus*, *Kaloula* and *Microhyla* (Ramaswami, 1932a), *Glyphoglossus* (Ramaswami, 1932b), and *M. carolinensis* (Roux, op. cit.) possess a large extraplectral, although in *Phrynellia* (Ramaswami, 1936) it is simple and rod-like. This structure is, however, not diagnostic of the *Microhylidae*, having been described in a variety of Anurans including *Arthroleptella* (de Villiers, 1929), *Phrynomerus* (de Villiers, 1930), *Cacosternum* (de Villiers, 1931d), *Bufo angusticeps* (Schoonees, 1930) and *Heleophryne* (C. A. du Toit, 1930).

The perichondrally ossified pars media plectri, following a somewhat tortuous course posteriorly, is directly continuous with the pars externa plectri (Text-fig. 7b). Posteriorly the pars media is closely applied to the auditory capsule, being separated from it by a strip of connective tissue. (Text-fig. 7c). In this region it is intensely perichondrally ossified leaving only a minute calcified cartilaginous core. The pars media gains synchondrotic continuity with the lateral cartilage ledge of the auditory capsule and at this point it divides into two prongs, the medial of which passes into the pars interna (Text-fig. 6a). The pars interna plectri is poorly developed, being syndesmotically attached to the ventrolateral wall of the lateral semicircular canal; the connective tissue disappears at one point and synchondrotic continuity is established.

The pars interna lies medially to the operculum, being separated from it by a small, but distinct synovial cavity, and disappearing shortly after the appearance of the latter. The portion of the pars media which is continuous with the ventrolateral cartilage ledge persists further posteriorly than its medial prong, and helps to form a ventrolateral support for the ductus fenestrae vestibuli.

The operculum forms the dorsolateral support for the ductus fenestrae vestibuli which occupies most of the extensive space of the fossa fenestrae vestibuli. It is a large, medially concave, saucer-shaped structure, its dorsomedial tip being synchondrotically connected to the lateroventral wall of the lateral semicircular canal (Text-fig. 6b). At the level of the foramen ovale the connection becomes syndesmotic, a connective tissue strip extending from the operculum to an expanded foot ventrolaterally to the lateral semicircular canal (Text-fig. 6c). This foot consists of hypertrophic

cartilage cells peripherally ossified by the exoccipital which invades the entire cartilage in the posterior region of the foramen ovale. The operculum is perichondrally ossified at intervals on its lateral and medial periphery and even shows signs of incipient eunchondral ossification (Text-fig. 6c).

(See Text-fig. 6, p. 224). The operculum in *Ascarphus* is calcified (de Villiers, 1934a), and a distinct margin of perichondrial bone has been described on the lateral surface of this structure in *Microbatrachella* (de Villiers, 1934b). Similarly in *Crinia* (C. A. du Toit, 1934), the posterior portion of the operculum is weakly perichondrally ossified. In no Anuran which has hitherto been investigated, however, is the ossification as extensive as in *Elachistocleis*.

The opercularisation of the musculus levator scapulae superior is a common feature among the *Anura*. In *Hemisus* (de Villiers, 1931a), *Ascarphus* (de Villiers, 1934b), *Liopelma* (Wagner, 1934b), *Spelaeophryne* (de Vos, 1935) and in *Elachistocleis*, however, the entire m. levator scapulae superior is opercularised, a condition which would, according to de Villiers (1931a), indicate increased terrestrialisation.

The ganglion glossopharyngei is situated dorsally to the operculum, a good distance anterior to the ganglion jugulare, as in *M. carolinensis* and *Callulina* (Roux, op cit.), a condition which should be regarded as neotenic (cp. Gaupp, 1899, p. 149).

THE UPPER JAW AND SUSPENSORIAL REGION.

In the region of the bursa angularis oris, the maxilla loses its connection with the pterygoid process and comes to lie laterally to the masticatory muscles. It continues posteriorly as a tiny splint-like process ending freely beneath the skin near the level at which the annulus tympanicus first appears in section. The processus pterygoideus is encased dorsally, medially and ventrally by the pterygoid bone, a dorsally directed process of which also invests the ventral and ventromedial edges of the otic process (Text-fig. 7a). The connective tissue separating the bone from the cartilage disappears at intervals but there is no sign of ossification of the latter.

The homologies of the various processes in the suspensorial region have been the subject of a good deal of controversy since the time of Huxley and Parker. An admirable account of the history of the problem is given by Pusey (1938). De Beer (1926, quoted from de Beer, 1937, p. 207) pointed out that the basal process in *Anura* which had been regarded as homologous with the basal process in *Urodela* by Gaupp (1892) and subsequent authors is no true basal process at all. The palatine nerve in *Urodela* runs

down behind the basitrabecular and basal processes and then forwards beneath them, whereas in *Anura* the nerve leaves the skull in front of and medially to the basal process. The latter should, therefore, be regarded as a pseudobasal process. Pusey concludes that the pseudobasal process is formed from the basitrabecular process and the post-palatine commissure, which have become detached from the skull and secondarily fused to the quadrate.

(See Text-fig. 7, p. 226). The processus pseudobasalis appears to project from the medial surface of the processus oticus as in *Rana grayi* (C. A. du Toit, 1933) and before losing its connection with the processus oticus, is supported ventromedially by the pterygoid (Text-fig. 5b). After severance of this connection, however, this portion of the pterygoid is lost, and the posteriorly directed processus pseudobasalis articulates with a ventral process of the auditory capsule (Text-fig. 7c). It disappears shortly after communication of the tympanic cavity with the buccal cavity is established. The ventral cartilaginous process with which the pseudobasal process articulates, now broadens out to form a ventrolateral ledge of the auditory capsule (Text-fig. 6a). The pars media plectri is attached to it dorsolaterally and the hyoid cornu is fused to it ventrally. The point at which the hyoid cornu is detached from it is seen in Text-fig. 6b.

An examination of text-figures 7 and 6 will show that the crista parotica, which forms a dorsolateral extension of the auditory capsule in text-figure 7a is reduced posteriorly whereas the ventrolateral cartilage simultaneously increases in proportion. This ledge forms a ventral and ventrolateral support for the ductus fenestrae vestibuli which is prolonged into the extensive fossa fenestrae vestibuli (Text-fig. 6b). The lateral wings of the parasphenoid extend underneath it (Text-figs. 6c and 5a). It is invaded posteriorly by the exoccipital (Text-fig. 5b) and it ends freely behind the auditory capsule as a posteriorly directed bony process underlying the glossopharyngeal nerve lateroventral to the vena capititis lateralis.

The fusion of the otic process with the skull is normal. Immediately anterior to the severance of the pars articularis from the processus pseudobasalis, the former develops a lateroventrally directed much-calcified process. This calcification extends along the articular surface of the pars articularis which shows signs of incipient ossification. Similar histological conditions obtain in the articular region of Meckel's cartilage. At the point of severance of the processus pseudobasalis from the pars articularis, the quadrato-maxillary can be seen as a minute autochthonous bone separated from the lateroventrally directed calcified process of the pars articularis by a ligament (Text-fig. 7c). In the

next section it is seen to invade the lateroventral process simulating perichondral ossification. Posteriorly this lateral portion of the pars articularis acquires a considerable marrow cavity.

In the majority of Anurans the ossification of the quadrate cartilage is initiated by the quadratomaxillary. In *Breviceps* (de Villiers, 1931b, p. 12) and apparently also in *Probreviceps* (de Villiers, 1933, judging from figures), as well as in *Spelaeophryne* (de Vos, op. cit.) and *Callulina* (Roux, op. cit.), forms which lack a quadrato-maxillary, the quadrate cartilage is entirely unossified. In these genera a fusion of the pterygoid and paraquadrate bones occurs, which de Villiers (1933, op. cit.) considers to be in some way associated with the loss of the quadratomaxillary. Similar conditions with respect to the absence of a quadratomaxillary and the fusion of the pterygoid and paraquadrate bones obtain in *Hemisus* (de Villiers, 1931a).

Here, however, ossification from the pterygo-paraquadrate complex invades the quadrate cartilage. *Ascaphus* (de Villiers, 1934b), *Liopelma* (Wagner, 1934a and b) and *Scaphiopus* (Ramaswami, 1935b) lack a quadrato-maxillary, but a pterygoid-paraquadrate fusion does not take place. A true os quadratum is represented in *Ascaphus* (de Villiers, op. cit.); in *Liopelma* (Wagner, op. cit.), the cartilage is much calcified and shows signs of incipient perichondral ossification in the articular region. In *Cacosternum* (de Villiers, 1931d) a quadratomaxillary is present but the quadrate cartilage is entirely unossified, a condition apparently considered by de Villiers (1936, p. 228) to be neotenic.

Another feature of interest in the suspensorial region is the presence of a diverticulum of the tympanic cavity situated medially to the crista parotica. It is shown in text figure 7a at a point immediately anterior to its communication with the general tympanic cavity. The presence of a diverticulum medially to the crista parotica is, as far as I am aware, unique among Anurans.

THE LOWER JAW. (See Text-fig. 8, p. 228).

The relations of the lower jaw are typically Microhylid. The mentomandibular is perichondrally as well as enchondrally ossified, except medially and laterally where large hypertrophic cartilage cells persist. The mental symphysis is effected by large, loosely packed cartilage cells. An interesting feature is the presence of a strip of connective tissue intervening between the mentomandibular and the rest of Meckel's cartilage (Text-fig. 8). This has not been previously described in any of the *Microhylidae*. It is possible that the infrarostral cartilage alone may have given

rise to the mentomandibular, so that the former never became confluent with Meckel's cartilage during development. This would indicate a neotenic condition. On the other hand, a connection may have been established and become lost secondarily. Whatever its origin, the presence of connective tissue between the mentomandibular and the adult Meckel's cartilage can be correlated with increased movability of the mentomandibulars and with what might be termed an incipient viscero-cranial kinesis.

A step towards the emancipation of the mentomandibulars is achieved in the *Brevicipitinae* and in certain other *Microhylidae* by the intervention of a strip of connective tissue between the mentomandibular and the dentary. This condition obtains in *Breviceps*, *Probreviceps* (de Villiers, 1933), *Spelaeophryne* (de Vos, op. cit.), *Callulina* and *M. carolinensis* (Roux, op. cit.) and *Glyphoglossus molossus* (Ramaswami, 1932b).

The mentomandibular is produced posterolaterally as a bony spur with cartilaginous tip, running parallel to the lower jaw. This "lateral epiphysis of the mentomandibular" first mentioned by Devanesen in 1922 occurs constantly in the *Microhylidae*, having been described in the Indian *Cacopus* (Devanesen, 1922), *Glyphoglossus*, *Microhyla*, *Kaloula*, *Cacopus* (Ramaswami, 1932a and b), in the South African *Phrynomerus* (de Villiers, 1930a), *Breviceps* and *Probreviceps* (de Villiers, 1931c, 1933), in the East African *Spelaeophryne* (de Vos, 1935) and *Callulina* (Roux, op. cit.), in the Malagasy *Rhomboophryne* (de Villiers, 1934a), as well as in the American *Microhyla carolinensis* (Roux, op. cit.). C. A. du Toit (1938, p. 407) mentions a similar though much smaller process in *Anthroleptides* and concludes that this form may represent a member of the ancient Ranid stock from which the *Microhylidae* have evolved.

I had the opportunity of examining Roux's sections and find remarkable similarities in the lower jaws of *M. carolinensis* and *Elachistocleis* especially in regard to the lateral epiphysis and gular musculature.

The *musculus submentalis* is enlarged as in all *Microhylidae* and is attached to the lateral epiphysis of the mentomandibulars. The dentary and gonial are well-developed and edentulous. The gonial extends almost as far forward as the dentary. The latter establishes no connection with the mentomandibular. Intensive calcification of Meckel's cartilage occurs in the suspensorial region.

THE HYOID APPARATUS. (See Text-fig. 9, p. 226).

The least width of the hyoid plate is slightly greater than its median length. De Villiers in his work on *Phrynomerus* (1930) ascribes this predominantly transverse develop-

ment of the corpus to the presence of a very large intermanubrial bay (Ridewood's "hyoglossal sinus") which is continued into the corpus (Text-fig. 9). The cornua principalia (hyalia) fuse with the otic capsules. Each has a broad anterolateral flange of thin procartilage differing in texture from the rest of the cartilaginous hyoid. According to Trewavas (1933) this lateral flange or "extra-hyal" represents the anterior process of the hyoid which has curved round laterally and fused with the hyale. In *Breviceps adspersus* the anterior process is curved laterally with its distal end almost fused to the hyale. The fusion is complete in *B. gibbosus* so that a fenestra is enclosed (Trewavas, op. cit.).

This interpretation might be applied to the condition obtaining in *Breviceps fuscus* and *Probreviceps ulugurensis* (de Villiers, 1931c and 1933). De Villiers, however, states that the anterior process of the hyale is absent in these forms and mentions a thin cartilaginous bar joining the manubrium to the hyale. A similar ovoid fenestra is described by Roux (op. cit.) for *Callulina krefftii*. De Vos in her work on *Spelaeophryne* (de Vos, 1935) concludes that the anteriorly directed appendage of the hyale can be derived from the *Breviceps gibbosus* type by loss of the median portion of the looped anterior process, a statement which could only be verified by studying the development.

Trewavas's "Gastrophryne group" including *Kaloula pulchra*, *Pseudohemisus longimanus*, *Oreophryne celebensis*, *Microhyla beadmorei*, *M. ornata*, *M. inornata*, *Gastrophryne terensis*, *M. okinavensis* (Frazier, 1924) and *Cacopus systoma* (Devanesen, 1922), have a number of characteristics in common, most of which distinguish them sharply from other firmisternous forms. In this group the anterior process is completely fused with the hyale, thus obliterating the fenestra, a condition which has also been described by Roux for *M. carolinensis* (op. cit.). Similar conditions are present in *Elachistocleis*. It is apparent, both from the work of Trewavas and especially of Blume (Blume, 1929), that these processes are particularly subject to modification: striking variations occur even in members of the same species, whereas the anterior processes in a form as distantly related to the Brevicepitids as *Cacosternum capense* (Trewavas, fig. 64, p. 484) corresponds exactly to the condition in the "Gastrophryne group." The phylogenetic importance of this structure is, therefore, negligible.

The alary processes are broad structures not separated from the corpus by a neck as in *Rana*. The posterolateral processes are small pointed structures diverging from the corpus at right angles to its longitudinal axis.

The osseous thyreoid processes have small distal cartilaginous epiphyses. They are separated at their bases

by a pad of intensely calcified hypertrophic cartilaginous cells, which is produced into a short ventral process. The presence of this median ventral thickening in the corpus between the bases of the thyreoid processes has been noted in *Phrynomerus* (de Villiers, 1930), *Microhyla okinavensis* and *Cacopus* (Ramaswami, 1932) where it is cartilaginous, and in *Breviceps* (de Villiers, 1931c), *Kaloula* and *Microhyla* (Ramaswami, op. cit.) where it is ossified. A similar ossified structure is present in *Microhyla carolinensis* (Roux, op. cit.) and *Callulina krefftii* (Roux, op. cit.).

A peculiar feature of the thyreoid process of *Elachistocleis* is the sharp lateral bend present at about the middle of its length so that the distal ends of these processes are not only dorsally directed as in all *Microhylidae*, but are also widely diverging so as to enclose the well-developed larynx.

NEOTENIC FEATURES OF THE SKULL.

The phenomenon of neoteny which is common among the *Anura* as a group, exhibits itself in the most interesting variety of ways, some families being more subject to it than others. Although the environmental factors responsible for the retention of larval features in the adult are not yet fully known, the study of the cranial anatomy of *Elachistocleis* has brought certain new aspects of the problem to light.

The separation of the nasal capsules anteriorly by an internasal space as in *Urodeles* was observed by Born in *Pelobates* (op. cit.). It is interesting to note that similar conditions have expressed themselves in two closely related Microhylid genera, *Microhyla carolinensis* and *Elachistocleis ovalis*. Whether habit has been causal to structure in this instance, it is difficult to determine.

From the work of Dr. C. A. du Toit (op. cit.) it appears that the fusion of the lamina inferior of the crista intermedia with the solum is a fairly common occurrence in many Ranids. This may be correlated with the fact that during development the recessus lateralis of the cavum inferius which is laid down behind the recessus medialis and later expands from behind forwards, has failed to do so in certain forms. Consequently there is no need for additional space in the anterior region of the nasal capsule, so that the lamina inferior and even the crista intermedia fail to separate anteriorly from the solum. Similar neotenic conditions obtain in *Elachistocleis* and will probably prove to be a general feature of a large number of *Microhylidae*.

The relations of the perilymphatic foramina in *Elachistocleis* are neotenic. Both foramina communicate directly with the cranial cavity anterior to the jugular foramen. The ganglion glossopharyngei is separated from the ganglion

jugulare as in *M. carolinensis* and *Callulina* (Roux, op. cit.). This is apparently a neotenic feature (Gaupp, op. cit.).

The relations of the lower jaw are particularly interesting. Here the mentomandibular is completely separated from the rest of Meckel's cartilage by a strip of connective tissue. Should this state of affairs have resulted from the failure of the infrarostral cartilage to fuse with the rest of Meckel's cartilage during development, it may be regarded as neotenic.

SUMMARY.

1. A median groove is present in the anterior region of the nasal capsule, probably corresponding to the Urodelan internasal space. Anteriorly, therefore, the nasal capsules have their own inner walls.
2. Rotation and consequent modification of the anterior and anteroventral portion of the nasal capsule appears to have taken place.
3. The tectum nasi is poorly developed and the cartilago obliqua is attached anteriorly to the lateral edge of the nasal.
4. The planum terminale of the cartilago obliqua fuses posteriorly with the lamina inferior.
5. The anterior portions of the crista intermedia and lamina inferior are fused to the solum.
6. The lamina superior fuses with a calcified elevation of the solum.
7. A complicated cartilaginous support for the eminentia olfactoria is present.
8. Only the first Gauppiian "Wulst" is present.
9. The nasolacrimal duct communicates with a combined opening formed by the fusion of the lateral portion of the cavum medium and a lateral infundibular recess.
10. A well-developed glandula intermaxillaris is present, some of its tubules being prolonged into the cartilaginous support of the eminentia olfactoria.
11. A gland of unknown significance occurs in the nasal capsule.
12. The "Rachendrüse" is divided into a medial and a lateral group of tubules.
13. Two prechoanal sacs are present.
14. The bursa angularis oris is well-developed.
15. The nasal roof almost the entire nasal capsule.
16. The palatines are absent.
17. The "os-en-ceinture." is paired throughout.

18. The *taenia tecti medialis* is present, but there is no *taenia tecti transversalis*.
19. The trochlear foramen is situated anterodorsally to the optic foramen.
20. The perilymphatic foramina open into the cranial cavity.
21. The jugular foramen faces dorsolaterally.
22. The *annulus tympanicus* is sickle-shaped.
23. The proximal part of the *pars media plectri* divides into two prongs.
24. The operculum shows signs of incipient enchondral ossification.
25. The ganglion glossopharyngei is situated anteriorly to the ganglion jugulare.
26. The *processus pseudobasalis* articulates with a ventral process of the auditory capsule which posteriorly forms a lateral cartilage ledge of the auditory capsule.
27. The *cornu principale* which possesses an "extra-hyal" is confluent with the otic capsule.
28. A ventral process of hypertrophic cartilage cells occurs between the thyreoid processes of the hyoid.
29. The mentomandibular with its lateral epiphysis is separated from the rest of Meckel's cartilage by a strip of connective tissue.

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BIBLIOGRAPHY.

- BLUMM, W.:** Ueber das Hyoid einiger einheimischer Anuren. *Gegenb. Morph. Jahrb.*, 61: 15 (1929).
- BORN, G.:** Ueber die Nasenhöhlen und den Thränennasengang der Amphibien. *Gegenb. Morph. Jahrb.*, 2: 577 (1876).
- BOULENGER, G. A.:** Catalogue of the Batrachia Salientia s. Ecaudata in the Collection of the British Museum. 2nd Edition. London (1892).
- COHN, L.:** Zur Kenntnis der Mundrüschen einiger Anuren. *Zool. Jahrb.* Suppl. 12 (1910). (Quoted from Müller. 1932).
- DE BEER, G. R.:** Studies on the Vertebrate Head. II. The Orbito-temporal Region of the Skull. *Quart. Journ. Micr. Sc.*, 70: 263 (1926).
- DE BEER, G. R.:** The Development of the Vertebrate Skull. Clarendon Press, Oxford (1937).

- DEVANBENN, D. M.: Notes on the Anatomy of *Cacopus systoma*, an Indian toad of the family Engystomatidae. *Proc. Zool. Soc. Lond.*, p. 527 (1922).
- DR VILLIERS, C. G. S.: The Development of a Species of Arthroleptella from Jonkershoek, Stellenbosch. *S. Afr. Journ. Sc.*, 26: 481, (1929).
- DR VILLIERS, C. G. S.: On the cranial characters of the South African Brevicipitid, *Phrynomerus bifasciatus*. *Quart. Journ. Micr. Sc.*, 73: 667 (1930).
- DR VILLIERS, C. G. S.: Some features of the cranial anatomy of *Hemisus marmoratus*. *Anat. Anz.*, 71: 305 (1931a).
- DR VILLIERS, C. G. S.: Ueber den Schädelbau des *Breviceps fuscus*. *Anat. Anz.*, 72: 164 (1931b).
- DR VILLIERS, C. G. S.: Ueber den Schädelbau der Brevicipitidengattung *Anhydrophryne*. *Anat. Anz.*, 71: 305 (1931c).
- DR VILLIERS, C. G. S.: The Cranial Characters of the Brevicipitid Genus *Cacosternum* (Boulenger). *Quart. Journ. Micr. Sc.*, 74: 275 (1931d).
- DR VILLIERS, C. G. S.: *Breviceps* and *Probreviceps*. comparison of the cranial osteology of two closely related Anuran genera. *Anat. Anz.*, 75: 257 (1933).
- DR VILLIERS, C. G. S.: Die Schadelanatomic der *Rhombophryne testudo* Boettger in bezug auf ihre Verwandtschaft mit den malagasiischen Brevicipitiden. *Anat. Anz.*, 78: 269 (1934a).
- DR VILLIERS, C. G. S.: Studies of the cranial anatomy of *Ascaphus truei* Stejneger, the American "Liopelmid." *Bull. Mus. Comp. Zool. Harv. Col.*, 77: 1 (1934b).
- DR VILLIERS, C. G. S.: Some points in the Anatomy of *Microbatrachella capensis* (Hewitt), and their bearing upon the question of phylogenetic neoteny. *S. Afr. Journ. Sc.*, 31: 406 (1934c).
- DR VILLIERS, C. G. S.: Some aspects of the amphibian suspensorium with special reference to the paraquadrate and quadrato-maxillary. *Anat. Anz.*, 81: 225 (1936).
- DR VOS, C. M.: Spelaephryne and the bearing of its Cranial Anatomy on the monophyletic origin of the Ethiopian and Malagasy Microhylids. *Anat. Anz.*, 80: 241 (1935).
- DU TOIT, C. A.: Die Skedelmorphologie van *Heleophryne regis*. *S. Afr. Journ. Sc.*, 27: 426 (1930).
- DU TOIT, C. A.: Some Aspects of the Cranial Morphology of *Rana grayi* Smith. *Proc. Zool. Soc. Lond.*, p. 715 (1933).
- DU TOIT, C. A.: The cranial morphology of *Crinia georgiae* Tschudi (Cystignathidae, Amphibia). *Proc. Zool. Soc. Lond.*, p. 119 (1934).
- DU TOIT, C. A.: The cranial anatomy of *Arthroleptides dutoiti* Loveridge. *Anat. Anz.*, 86: 369 (1938).
- DU TOIT, G. P., AND DR VILLIERS, C. G. S.: Die Skedelmorphologie van *Hyperolius horstockii* as voorbeeld van die Polypedatidae. *S. Afr. Journ. Sc.*, 29: 449 (1932).
- DU TOIT, G. P.: On the cranial characters of *Phrynobatrachus natalensis* (Smith). *S. Afr. Journ. Sc.*, 30: 394 (1933).
- FAHRENHOLZ, C.: "Drüsen der Mundhöhle" in Handbuch der verg. Anat. der Wirbeltiere., 3: 115 (1937). Herausgeg. von Bolk, Göppert, Kallius und Lubosch. Urban und Schwarzenberg, Berlin und Wien.

- FRASIER, M.: *J. M. Physiol.*, Philadelphia, **39**: 285 (1924). (Quoted from Trewavas, 1933).
- FUCHS, H.: Von dem Ductus angularis oris der Arrauschildkröte (*Podocnemis expansa*). *Nachr. von der Ges. der Wiss. zu Gött.*, **6**: 131 (1931).
- GADOW, H.: "Amphibia and Reptiles." *Cambridge Nat. Hist.*, **3**: 139 (1901).
- GAUPP, E.: Anatomische Untersuchungen über die Nervenversorgung der Mund- und Nasenhöhlendrüsen der Wirbelthiere. *Gegenb. Morph. Jahrb.*, **14**: 436 (1888).
- GAUPP, E.: Beiträge zur Morphologie des Schädels I: Primordial-Cranium und Kieferbogen von *Rana fusca*. *Morpholog. Arbeiten, herausgeg. von G. Schwalbe*, **2**, Heft 2, S. 275 (1892).
- GAUPP, E.: A. Ecker und R. Wiedersheim's Anatomie des Frosches Auf Grund eigener Untersuchungen durchaus neu bearbeitet. Erste Abteilung: 1896. Zweite Abteilung: 1899. Dritte Abteilung: 1904. *Vieueg und Sohn, Braunschweig*.
- HELLING, H.: Das Geruchsorgan der Anuren, vergleichendmorphologisch betrachtet. *Zeitschrift für Anat. und Entw.*, **103**: 587 (1938).
- LUTZ, A.: *Mem. Inst. Oswaldo Cruz*. (1927).
- MERTENS, R.: *Blätt. Aq. Terr.*, **XL**, 16, p. 286 (1929). (Quoted from H. W. Parker, 1934).
- MÜLLER, E.: Untersuchungen über die Mundhöhlendrüsen der Anuren Amphibien. *Gegenb. Morph. Jahrb.*, **70**: 131 (1932).
- MÜLLER UND HELMICH: *Wiss. Ergeb. Deutsch. Gran-Chaco Exp., Amph. und Rept.*, **1** (1936).
- NOBLE, G. K.: The Phylogeny of the Salientia. The osteology and the thigh musculature: their bearing on Classification and Phylogeny. *Bull. Amer. Mus. Nat. Hist.*, **48**: 1 (1922).
- NOBLE, G. K.: The Biology of the Amphibia. *McGraw-Hill, New York and London* (1931).
- NOBLE, G. K., AND PARKER, H. W.: A Synopsis of the Brevicipitid Toads of Madagascar. *Amer. Mus. Nov.*, No. 232, p. 1 (1926).
- PARKER, H. W.: Parallel Modifications in the Skeleton of the "Amphibia Salientia." *Ach. Zool. Ital.*, **16**: 1240 (1931).
- PARKER, H. W.: A Monograph of the Frogs of the Family Microhylidae. *British Museum* (1934).
- PUSEY, H. K.: Structural Changes in the Anuran Mandibular Arch during Metamorphosis, with reference to *Rana temporaria*. *Quart. Journ. Micr. Sc.*, **80**: 480 (1938).
- RAMASWAMI, L. S.: The Cranial Osteology of the South Indian Engystomatidae (Anura). *Half-yearly Journ. Mysore Univ.*, **6**, No. 1, p. 1 (1932a).
- RAMASWAMI, L. S.: The Cranial Anatomy of *Glyptophryne melissa* (Günther). *Half-yearly Journ. Mysore Univ.*, **6**, No. 2, p. 1 (1932b).
- RAMASWAMI, L. S.: Contributions to our knowledge of the Cranial Morphology of some Ranid genera of Frogs. Part 1. *Proc. Ind. Acad. Sc.*, **1**, No. 2, p. 80 (1934).
- RAMASWAMI, L. S.: Contributions to our knowledge of some Ranid Genera of Frogs. Part 2 *Proc. Ind. Acad. Sc.*, **2**, No. 1, p. 1 (1935a).
- RAMASWAMI, L. S.: The Cranial Morphology of some examples of Pelobatidae (Anura). *Anat. Anz.*, **81**: 65 (1935b).

- RAMASWAMI, L. S.:** The Cranial Morphology of the genera *Kaloula* Gray and *Phrynella* Boulenger (Anura). *Proc. Zool. Soc. Lond.*, p. 1137 (1938).
- RAMASWAMI, L. S.:** Some Aspects of the Anatomy of Anura (Amphibia). A Review. *Proc. Ind. Acad. Sc.*, 19, No. 1, p. 41 (1939).
- RAMASWAMI, L. S.:** Some Aspects of the Chondrocranium in the Tadpoles of South Indian Frogs. *Journ. Mysore Univ.*, Sect. B. Sc., 1, Pt. 4, p. 15 (1940).
- SCHOONHES, D. A.:** Die Skedelmorphologie van *Bufo Angusticeps*, Smith. *This Journal*, 27: 456 (1930).
- TREWAVAS, E.:** The Hyoid and Larynx of the Anura. *Phil. Trans. Roy. Soc. Lond.*, Ser. B., 222: 401 (1933).
- ROUX, G. H.:** The Cranial anatomy of *Callulina kreffti* Nieden. *In press.*
- ROUX, G. H.:** The Cranial anatomy of *Microhyla carolinensis* (Holbrook). *In press.*
- WAGNER, D. S.:** The structure of the inner ear in relation to the reduction of the middle ear in the Liopelminidae (Noble). *Anat. Anz.*, 79: 20, (1934b).
- WAGNER, D. S.:** Liopelma Studies No. 2. On the Cranial Characters of *Liopelma hochstetteri*. *Anat. Anz.*, 79: 65 (1934a).

LEGEND TO THE FIGURES.

Text-fig. 1.

Graphical reconstruction of the nasal capsule of *Machistocleis*. X 30. a, Ventral view; b, Dorsal view; c.al., cartilago alaris; ch., choana; c.obl., cartilago obliqua; c.pre.inf., cartilago prenasalis inferior; c.pre.sup., cartilago prenasalis superior; c.prom., crescent-shaped anteriorly directed cartilaginous prominence; em.of., eminencia olfactoria; for.nasobas., foramen nasobasale; for.pro.n., foramen pro ramus communicans cum n. palatino; l.sup., lamina superior cristae intermediae; mx., maxilla; n., nasal; pt.ter., planum terminale; pmx., premaxillary; p.mx.a., processus maxillaris anterior; sol.nas., solum nasi; spmx., septomaxillary; tect.nas., tectum nasi; v.a.p., ventral anteriorly directed process of septum nasi; vo., vomer.

Text-fig. 2.

Consecutive transverse sections through the region of the external nasal aperture. con.t., connective tissue; cv.p., cavum principale; d.g.l.n.l., efferent duct of glandula nasalis lateralis; f.f., foramen frontale through which the right ramus externus narium passes; f.f.s., fusion of folds of skin to form niche-like recess of vestibulum; f.s., folds of skin guarding external nose; gl.n.inf., glandula nasalis infundibularis; G.W., first Gauppin "Wulst"; inf., infundibular recess; i.s., internasal space; i.w., inner wall of nasal capsule; ly.g., lymph gland; m.lat.nar., musculus lateralis narium; op.g.l.n.l., opening of glandula nasalis lateralis; pl.obl., plica obliqua; r.m.n., ramus medialis narium; s.n., septum nasi; sol.n., plus cr.int., fused solum nasi and crista intermedia; v.r., niche-like recess of vestibulum.

Other abbreviations as in previous figure.

Text-fig. 3.

Consecutive transverse sections through the nasal capsule in the region of communication between the nasolacrimal duct and the nasal cavities. a.lac.d., anterior portion of nasolacrimal duct; a.rec.med., anterior wall of recessus medialis; b.r.l., branch of ramus lateralis; cr.int., cristaintermedia; glim., glandula intermaxillaris; g.l.n.l., glandula nasalis lateralis; g.l.n.m., glandula nasalis medialis; l.esol., plus Linf., fused lateral extension of solum and lamina inferior; l.inf., lamina inferior; m.med.nar., musculus medialis narium; rec.med., recessus medialis; r.i.n., ramus lateralis narium; spmx., septomaxillary; un.ep., zone of undifferentiated epithelium.

Other abbreviations as in previous figures.

Text fig 4

Consecutive transverse sections through the choanal region, blv, bloodvessel
 bon, branch of olfactory nerve, cpc's, common prechoanal sac, dglm, dorsal
 strand of glandula intermaxillaris, lpc's, left prechoanal sac, md, main duct of
 dorsal strand of glandula intermaxillaris, obc, common opening of prechoanal sacs
 into bucca cavity, pf, palatal fold, pli, pharyngeal processus lingularis,
 recl, recessus lateralis, Uem, inverted 'U' forming cartilaginous support of the
 eminentia olfactoria, vol, lateral portion of vomer, vom, medial portion of vomer.
 Other abbreviations as in previous figures

Text fig 5

Consecutive transverse sections through the posterior region of the auditory capsule
 dfv, ductus fenestrat vestibuli, exoc, exoccipital, fsp, foramen
 perilymphaticum superius, giph, ganglion glossopharyngei, lcl, lateral cartilage
 ledge of auditory capsule, lwp's, lateral wing of parasphenoid, mop, musculus
 opercularis, nvag, vagus nerve, op, operculum

Text fig 6

Consecutive transverse sections through the auditory capsul in the region of the sound conducting apparatus ch, cornu hyale, cont, connective tissue separating operculum from the auditory capsule, eosop, enchondral ossification of operculum, fhe, expanded foot of hypertrophic cartilage cells to which operculum is attached, lpr, lateral prong of pars media plectri, lsc, lateral semicircular canal, mpr, medial prong of pars media plectri, niph, glossopharyngeal nerve, pip, pars interna plectri, posop, perichondral ossification of operculum, ps, parasphenoid, rcomcumgiph, ramus communicans cum n. glossopharyngei, rop, ridge on operculum for attachment of m. opercularis
 Other abbreviations as in previous figures

Text fig 7

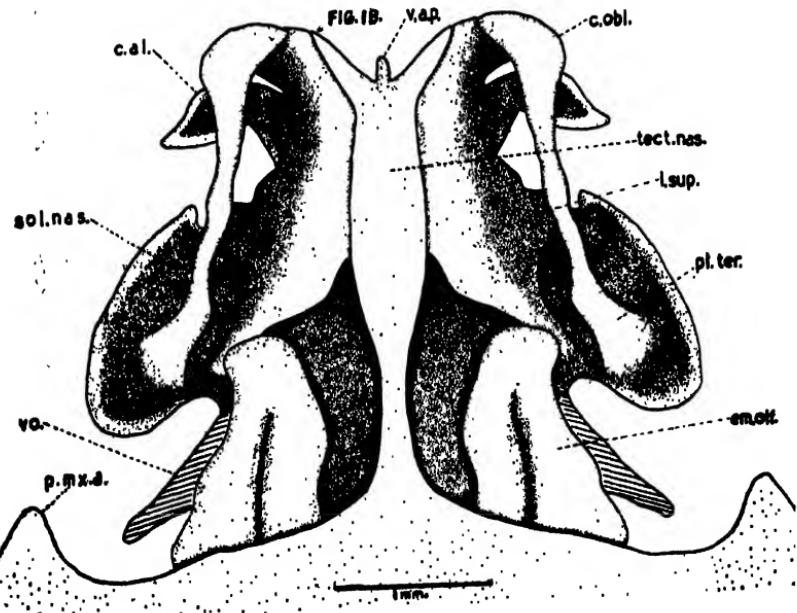
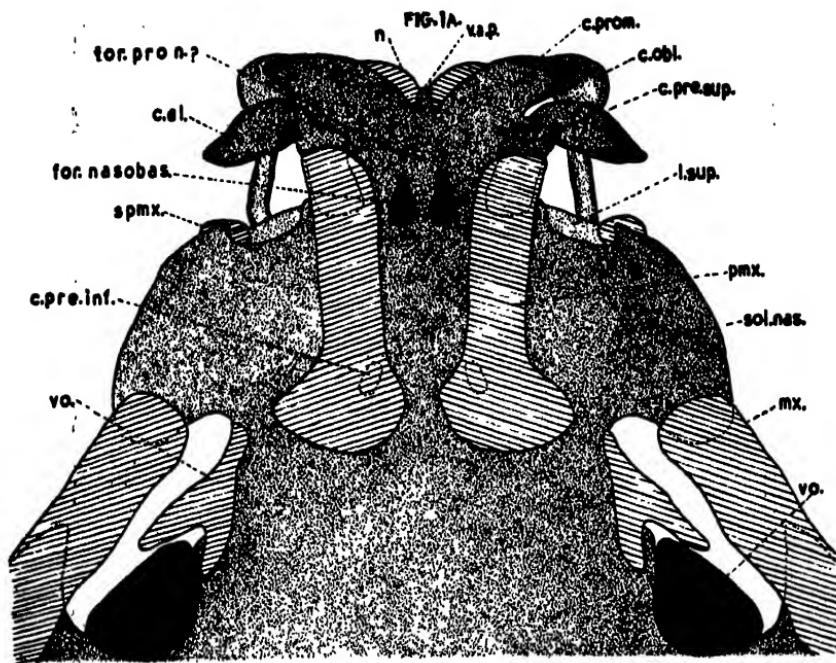
Consecutive transverse sections through the suspensorial region, acc, arteria
 carotis cerebralis, anty, annulus tympanicus, b'e, buccal epithelium, cep, crista
 parotica, divty, medial diverticulum of the tympanic cavity, fpro, foramen
 prooticum, gon, gonial, lcalcpr, lateroventrally directed calcified process of pars
 articularis, lig, ligament, Mc, Meckel's cartilage, oss M, incipient ossification
 in articular region of Meckel's cartilage, pira, pars articularis, pep, pars
 externa plectri, pmp, pars media plectri, pot processus oticus, pptg, processus
 pterygoideus, pqd, paraquadrate prot, prootic bone, prps, processus pseudo-
 basalis, ptg, pterygoid, qmx, quadratomaxillary, rhym, ramus hyomandibularis
 of facial nerve, tyc, tympanic cavity, vcp'l, vena capititis lateralis

Text fig 8.

Graphical reconstruction of the anterior region of the lower jaw of *Elachistocleis*.
 X 39 cont, connective tissue intervening between mentomandibular and the rest of
 Meckel's cartilage, den, dentary, lep, lateral epiphysis of the mentomandibular;
 mmd, mentomandibular, sym, symphysial region of hypertrophic cartilage cells
 Other abbreviations as in previous figures

Text fig 9

Graphical reconstruction of the hyoid apparatus of *Elachistocleis*. Dorsal view.
 X 16 cep, cartilaginous epiphysis, chy, corpus hyoideum, exhy, "extra hyal",
 hyc hypertrrophic cartilage cells which form a ventral process between the bases
 of the thyroide processes, hys, hyoglossal sinus', pal, alary process, ppl,
 posterolateral process, pth, thyroide process
 Other abbreviations as in previous figures



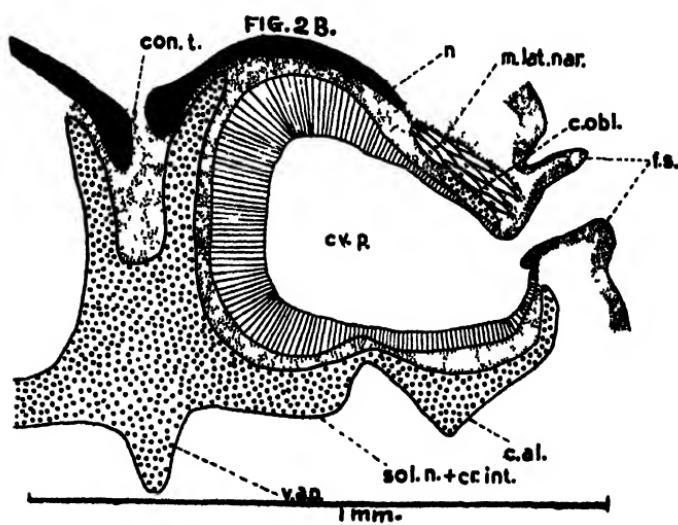
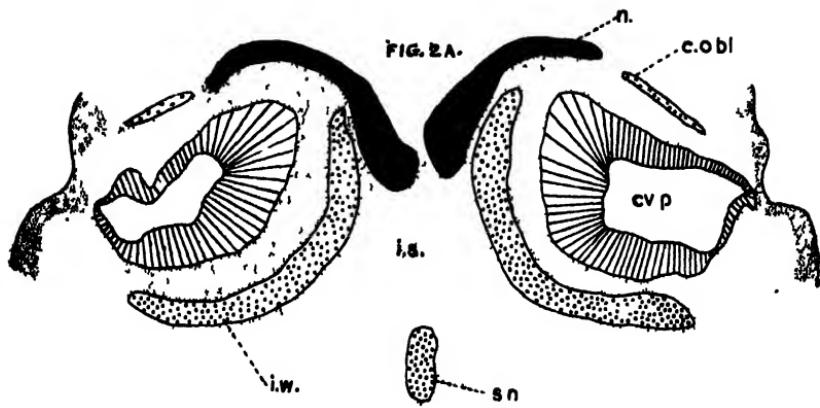


FIG. 2C.

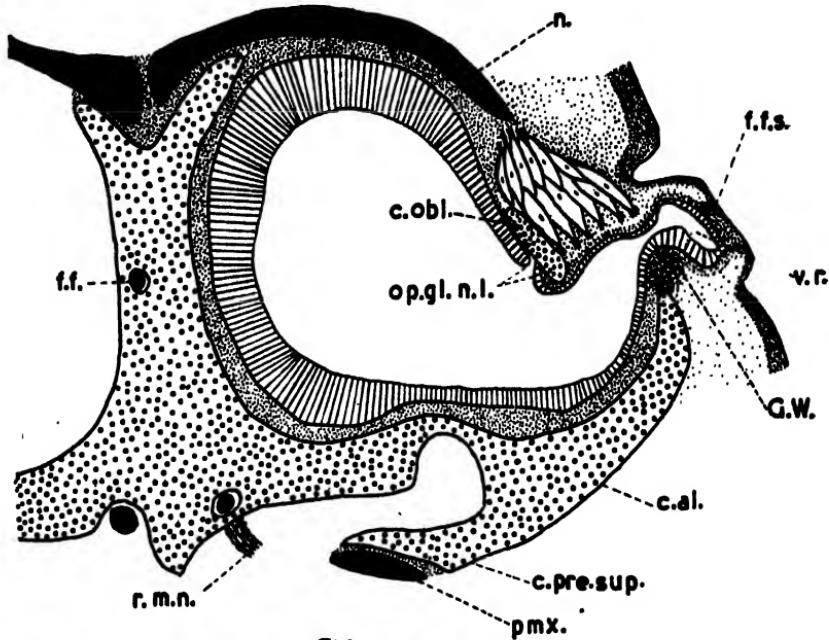


FIG. 2D.

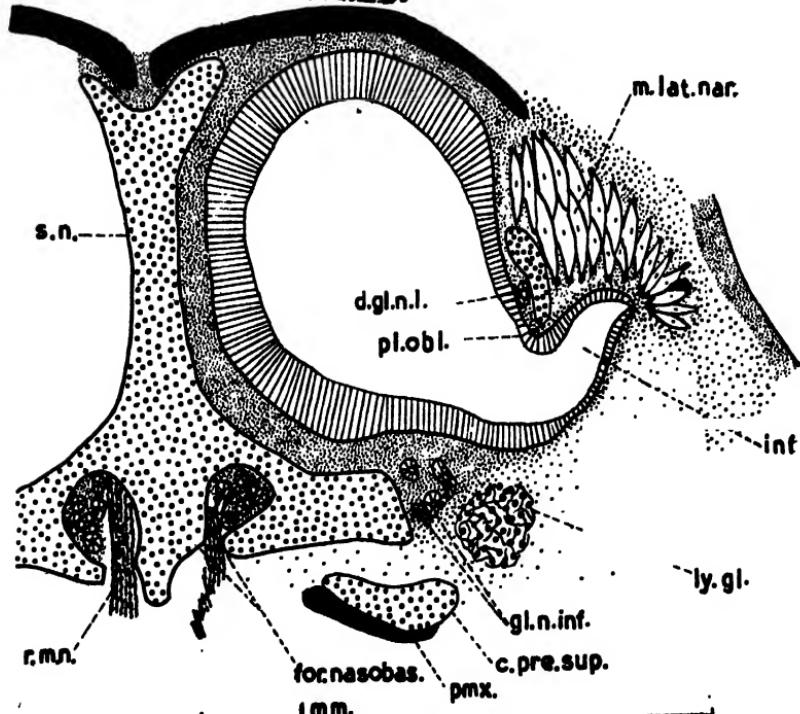


FIG. 3A.

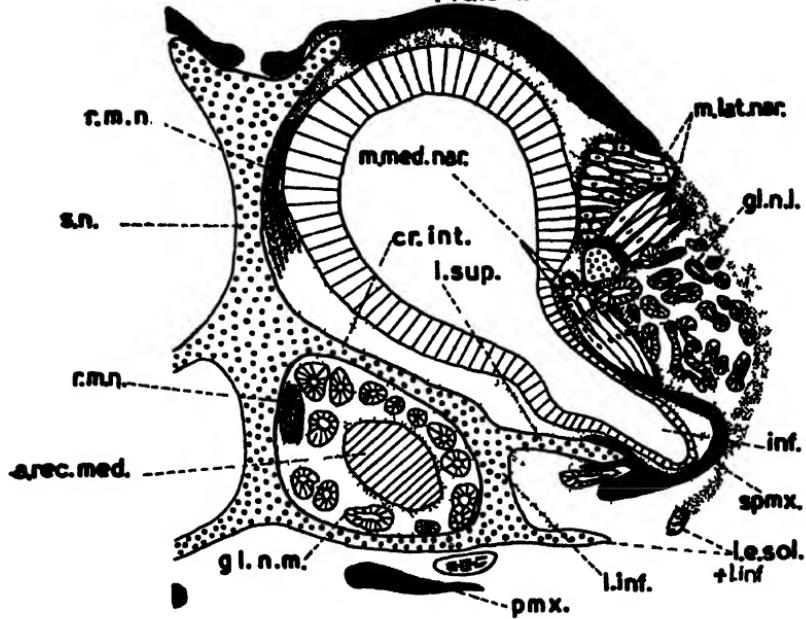
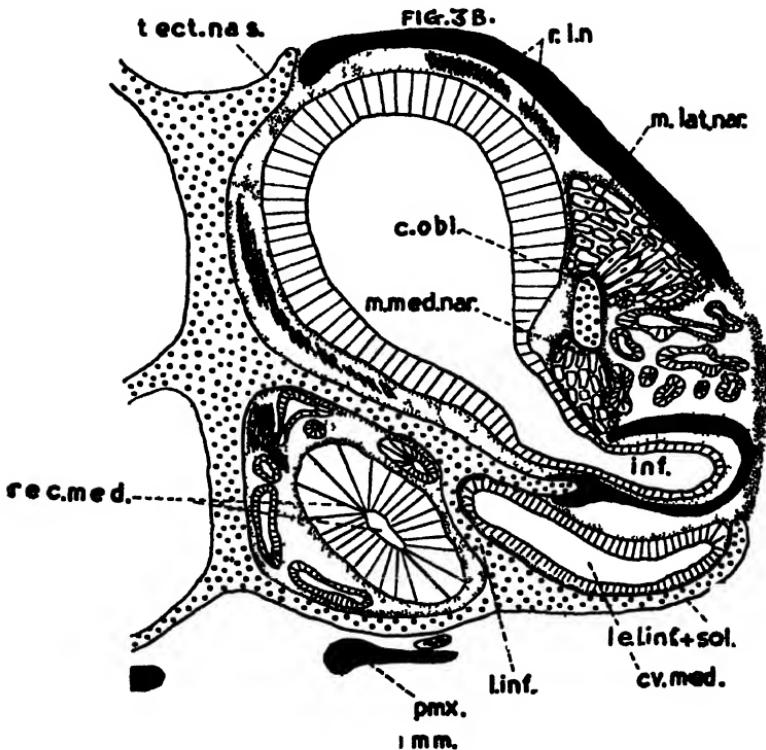


FIG. 3B.



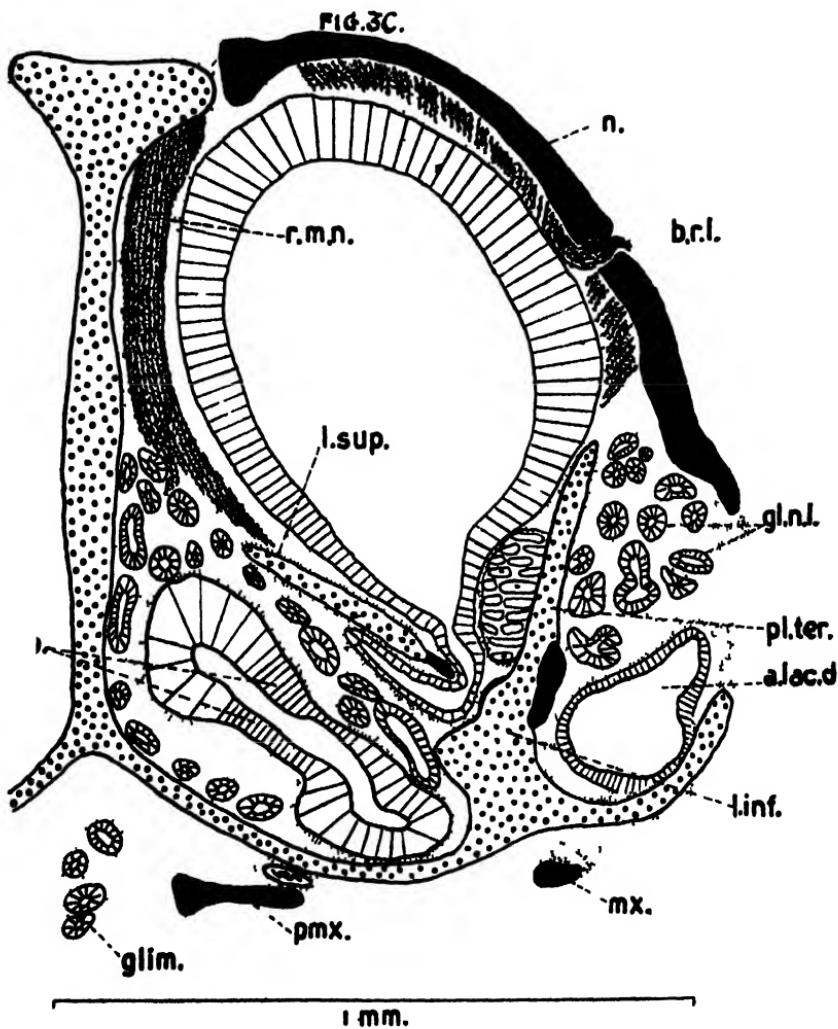


FIG. 4A.

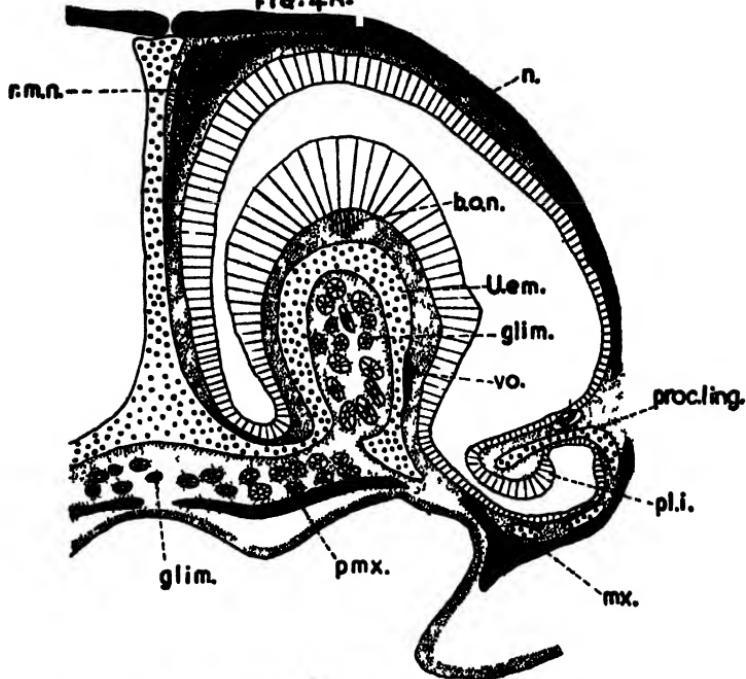
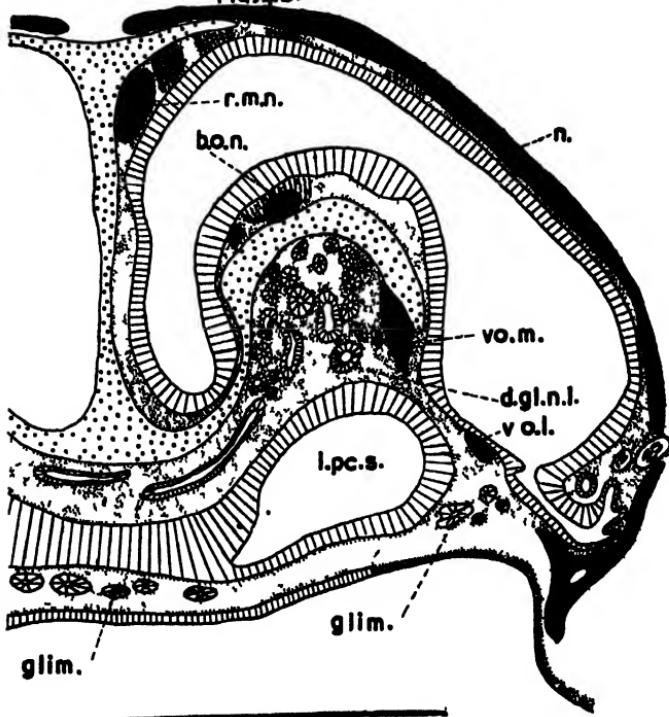
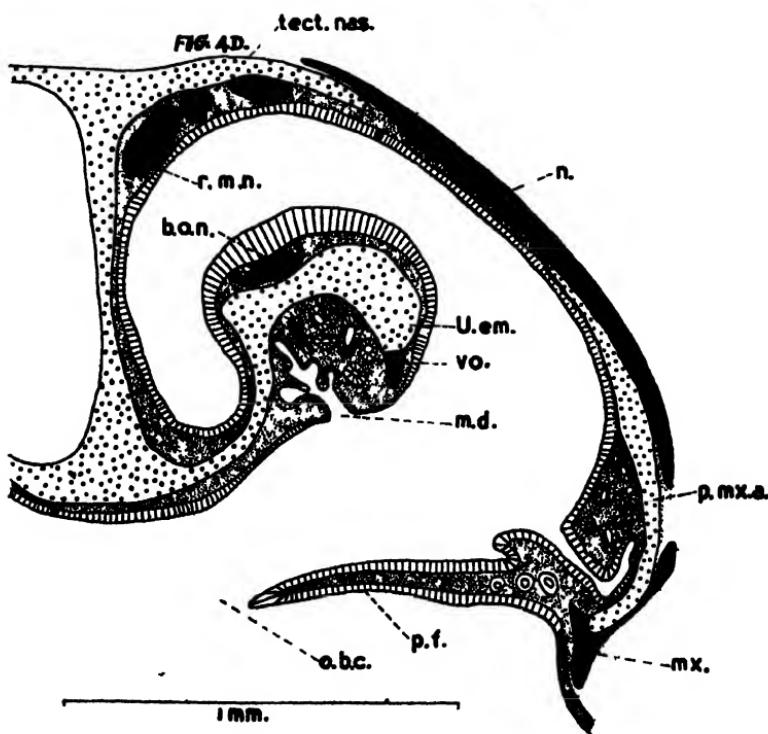
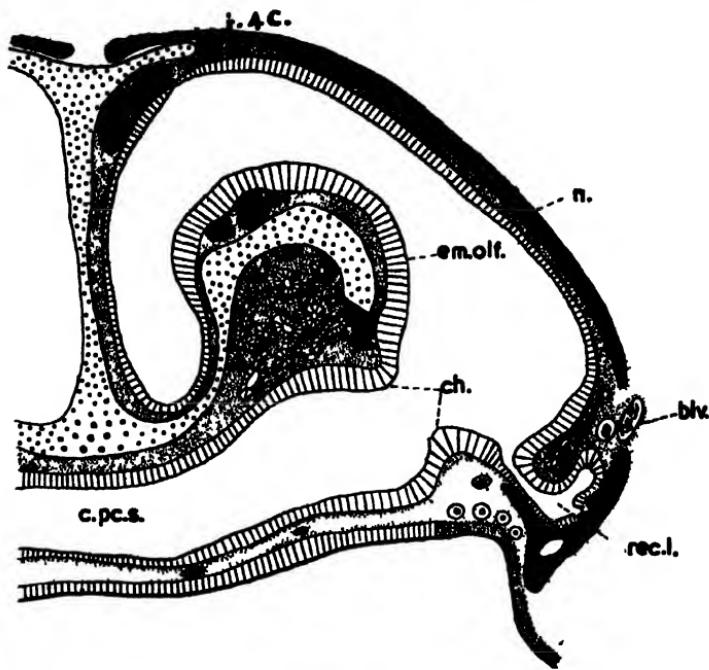


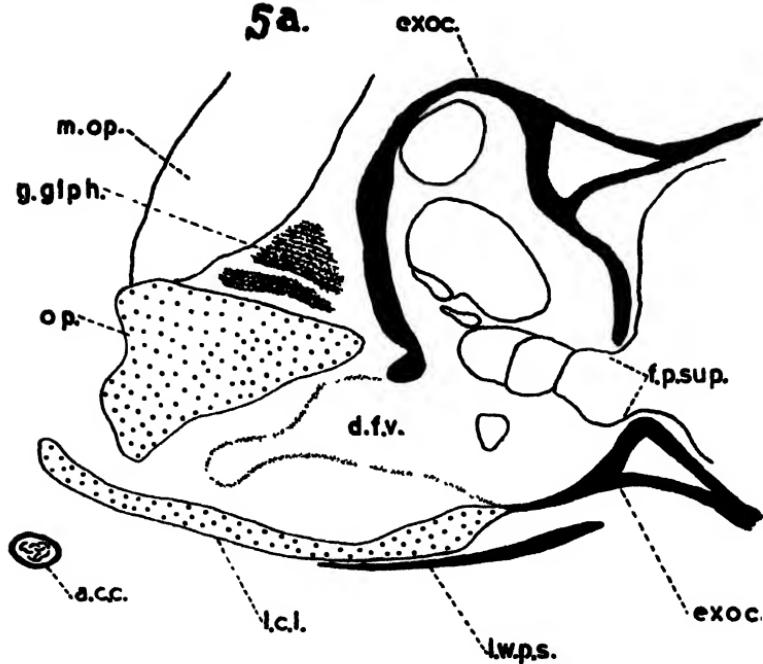
FIG. 4B.



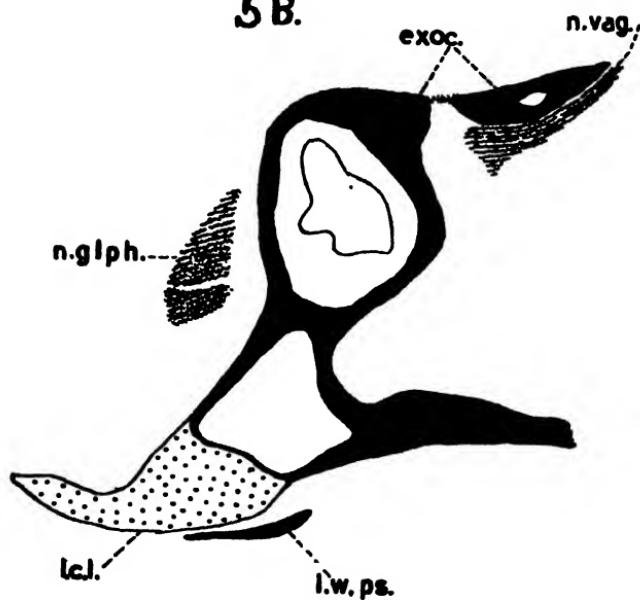
1 mm.



5a.



5B.



1 mm.

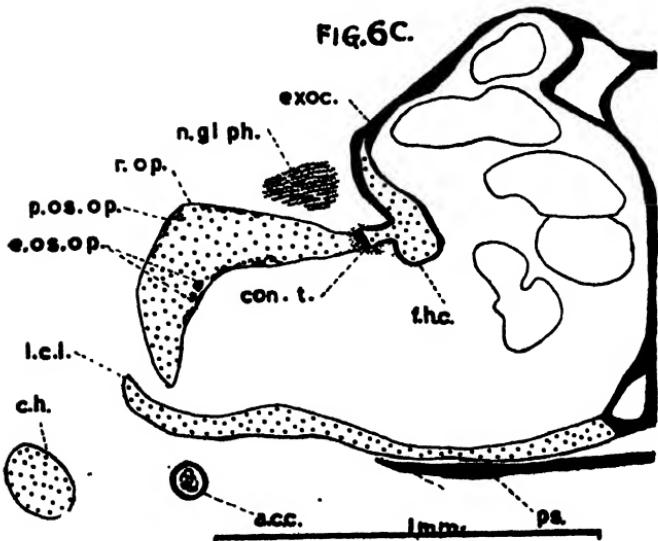
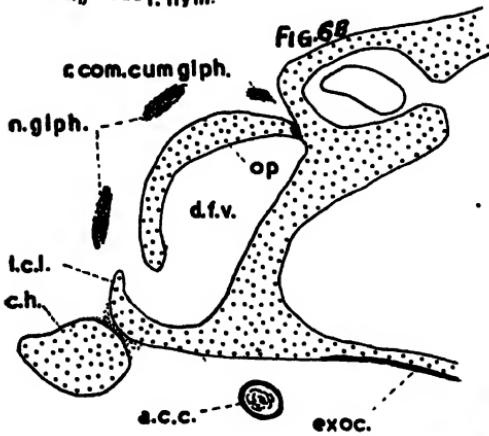
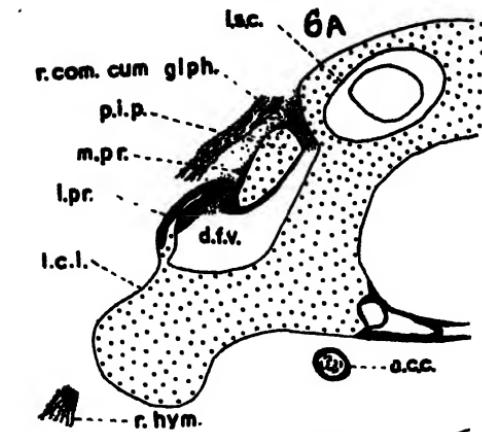


FIG. 7A.

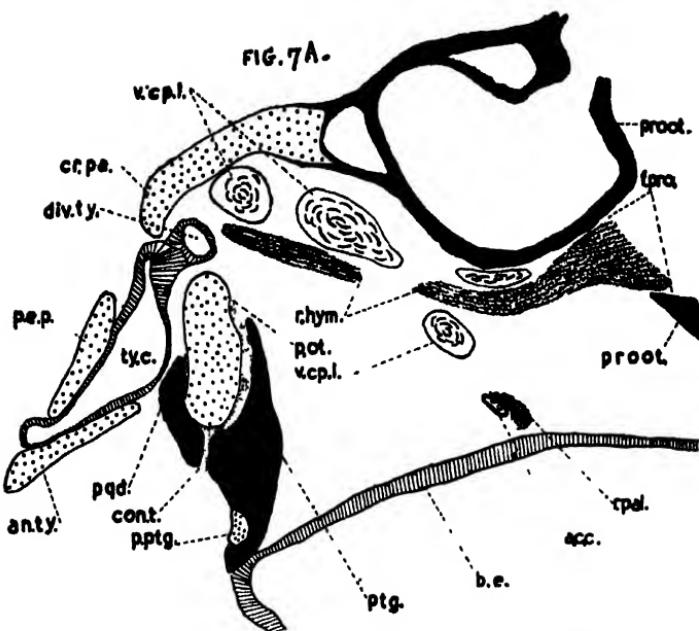


FIG. 7B.

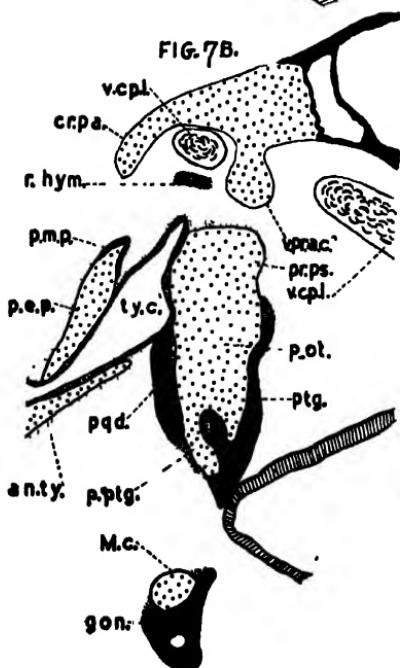
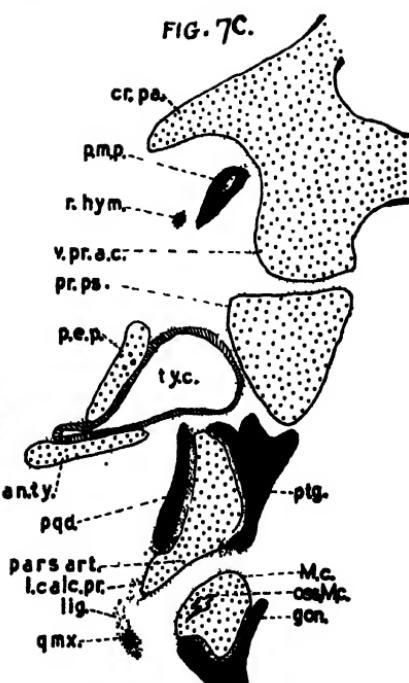
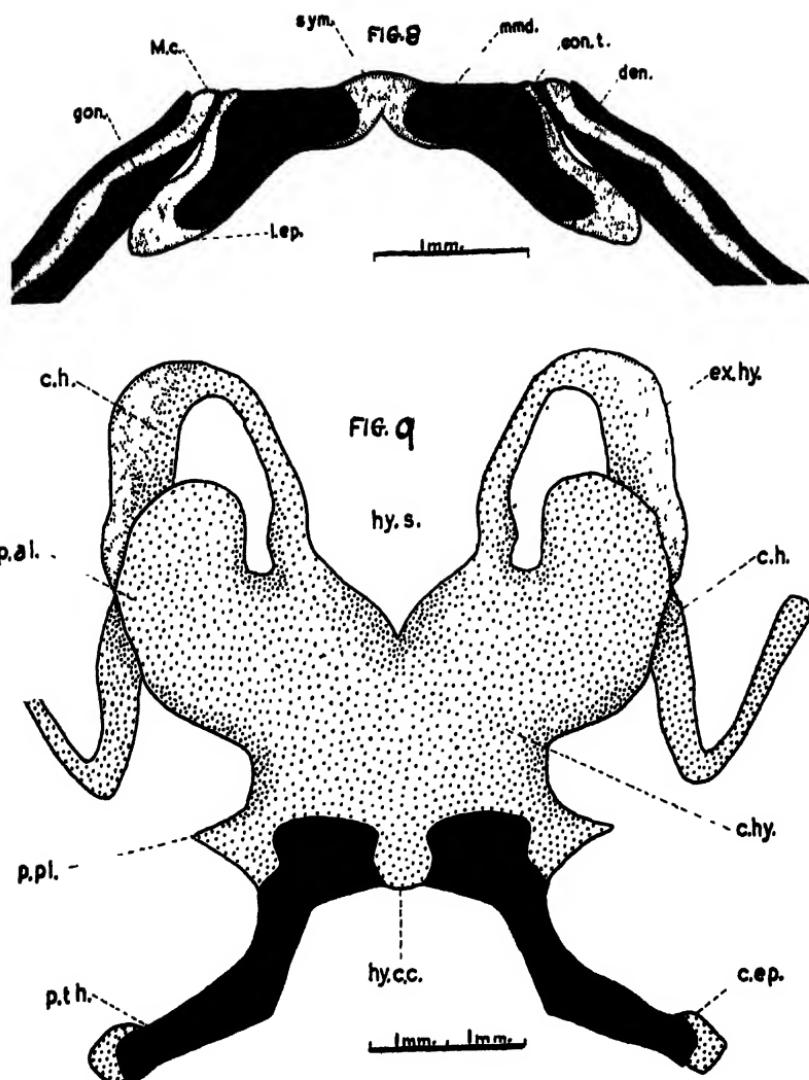


FIG. 7C.



1 mm.



SOUTH AFRICAN JOURNAL OF SCIENCE, Vol. XXXIX, pp. 227-234.
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A SURVEY OF HUMAN SKULLS EXHUMED IN THE VICINITY OF PORT ELIZABETH

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With 1 Table. Read 29th June, 1942.

The skulls discussed in this paper were obtained in and around Port Elizabeth; many of them were found in "kitchen middens" along the coast line or in the sandy beach itself. There are in all nineteen adult skulls, all of which, except for one belonging to the collection of the South African Museum, have been placed at our disposal by the Port Elizabeth Museum. A number of these skulls are incomplete, the basal region being most frequently absent. The specimens vary a great deal in their appearance of antiquity, but there is no evidence of true fossilization in any of them.

At a first glance the impression of a very heterogeneous group of skulls is presented, and this has been confirmed by subsequent analysis. The key to this heterogeneity has been found in the varying proportions of Negro characters present. On this basis the material has been divided into three groups. The first group, which is of appreciable antiquity, contains no recognisable Negro admixture. A variable but never preponderant Negro element can be identified in the skulls of the second group, while in the third group, apparently the most recent, the Negro characters have become predominant.

Two skulls were obtained from evidently recent burials. One of these presents typical Negro features without obvious dilution with other types; the other is classified as Eurafrikan on its large proportion of Caucasoid features. I have not considered it necessary to include these two specimens in the detailed analysis that follows.

Both metrical and non-metrical methods of analysis have been applied to the material and form the basis for a comparative study. Table 1 presents the principal metrical observations on these specimens. The non-metrical features have been considered on the criteria formulated by Galloway (1937) in his investigation of the Mapungubwe crania, with minor modifications.

DESCRIPTION OF CRANIAL TYPES.

1. *Non-Negro (Bush-Boskop) Group.* As far as records are available every one of these specimens was recovered either from a "shell midden" or from the sandy beaches of Port Elizabeth. The crania falling into this sub-division are characterised by their relative homogeneity, even in respect of detail. They are dolichocranial or slightly mesatricranial and this character is associated with constant chamaecephaly. Infantile frontal bossing is most frequently associated with a foetal parietal boss, giving the cranium a typically pentagonoid outline. Metrically this observation is borne out by the low values of the fronto-parietal index. Employing Frassetto's method, the majority of specimens fall into the chamaepentagonoid group. Five skulls show a slight degree of trigonism, whilst faint post-coronal flattening is constantly found in the group. A further pointer to the close similarity of the members of this group is the range of cranial capacities, which in only one instance exceeds 1220 ccs. This skull (562A) possesses a capacity of 1346 ccs., this increase is in harmony with the general trend of this specimen towards the robuster Boskopoid character evidenced by many of its chief features.

In lateral norma the low vault displays a characteristic contour. A moderately prominent glabella is associated with an ophryonic groove and a low, nearly vertical forehead. This passes into a flattened or slightly convex vault with the highest point usually at the bregma. The vault continues into the flattened, inclined parieto-occipital region. In most specimens the occipital torus and groove are well marked while the receptacula cerebelli are most frequently of moderate size. Supra-asterionic flattening always appears appreciable in extent. The parieto-temporal suture does not form an even convex curve but is usually flattened to some degree; nevertheless it rises above the level of the pterion. Exposure of the digastric fossa in lateral view is due to the small pointed mastoid process. The auditory region varies from the delicate "foetal" state to a moderately robust combination of structures. In no specimen is there such a well-marked mons temporo-sphenoidale as in the Zitzikama material (Laing and Gear 1929). An inferior frontal eminence appears in relatively few specimens. The facial skeleton, whether orthognathic or slightly prognathous, always displays alveolar prognathism.

The contour of the frontal region is low, angulated and flattened, with an indication of peaking, but no more. The moderately developed superciliarly ridges are associated with an excavated lateral supraorbital triangle and a somewhat projecting external angular process. The orbit varies from

a low quadrilateral to a high rectangular type, so that no typical shape can be determined. The nasal indices and the general morphology of the nasal region reveal a very constant type; a short wide nose is associated with an appreciable interorbital width, short flat nasal bones and broad inflated nasal processes of the maxillae which face chiefly anteriorly. The shallow subnasal region forms a further contribution to the typically chamaeprosopic face. Excavation of the infra-orbital region is always of moderate extent and related to the prominent malar region, which is to be traced to the presence of orbital shelving.

Characteristic features of the group are also found in the base of the skull. The foramen magnum varies in shape from circular to distinctly oval, the former being associated with rounded robust condyles, the latter with the flattened type. A shallow posteriorly expanded digastric fossa accompanies the small pointed mastoid process. Articular tubercles about the wide shallow glenoid fossa are of moderate size; the petro-tympanic fissure is typically visible in the floor of the fossa. The palate is a variable element, some of the group possessing a broad U-shaped, moderately shallow type, others again a pointed elongated one.

The internal aspect of the vault displays readily definable grooves for blood vessels; these are, however, not deep and canal-like. The cranial bone is thin except for localised areas at the bosses.

2. *Bush-Boskopoid Group with Negro Admixture.* The greater proportion of the six crania comprising this group were also obtained from the kitchen middens. Whilst the general trend of these specimens is towards a Bush-Boskop type, the presence of typically Negro features requires their separate consideration and classification. Homogeneity of the previous group is replaced here by a great diversity of feature.

Cranial indices show a preponderance of mesaticephalic type with both brachycranial and dolichocranial extremes. The available altitudinal indices suggest a relative increase in the height of the vault. The frontal bossing is infantile rather than foetal, though one specimen has an adult boss. On the other hand parietal bossing tends to be of foetal nature so that four of the members of this group possess a pentagonoid vault. The ellipsoidal vault of one specimen (296) represents the other extreme in shape that is encountered in the specimens. Trigonism is barely distinguishable, but post-coronal flattening is well marked in two crania. An interparietal groove is found exceptionally. With the exception of one skull of very low capacity, the members of this group are more voluminous than those of the first series, yet the greatest capacity does not exceed 1400 ccs.

The shape of the vault compares well with that of the previous group. In keeping with the vault height the parieto-temporal suture presents itself as an even convex curve. The mastoid region presents a moderately large process, posterior to which the digastric fossa is exposed. The mental region is generally robust in character. A mons temporo-sphenoidale and inferior frontal eminence are but slightly indicated. The face presents a moderate general prognathism.

Frontal region contour is rounded rather than angulated and occurs with distinguishable glabella and superciliary ridges, excavated lateral supra-orbital triangle and projecting process. Orbital shape lies between the narrow quadrilateral and high rectangular extremes. The nasal indices are all platyrhine. In general the nasal bones and aperture agree closely in type with the previous group. Exceptionally the interorbital region is narrow, with slight arching of the nasal bones. The subnasal region, however, tends to be deep and corrugated as the height of the face varies between two extremes, appearing leptoprosopic in one case. The malar region is angulated in some specimens, whereas in others it is evenly rounded.

An elongated foramen magnum is associated with rounded condyles. The shallow digastric fossa is expanded posteriorly. The glenoid fossa is most frequently deep and narrow, the related tubercles being prominent. The palate is frequently of the elongate U-shaped type, of moderate depth and rugosity. Grooves for arteries are well defined in the interior of the skull. The texture of the cranial bone is frequently on the massive side.

3. Predominantly Negro Group. This comprises but three skulls which were found to differ radically from the other groups; these crania do not present great similarity in detail. Perhaps of some significance is the fact that not one of these specimens was recovered from a kitchen midden.

Mesaticephaly is accompanied by frontal and parietal bosses that are most frequently infantile in nature, though the adult type is also represented. The bossing gives the crania a typical ovoid outline. In one specimen the vault is relatively high, in another fairly low. The cranial capacities all fall into the typical Negro range (1340-1465 ccs.)

The outline of the vault is constituted by a prominent glabella, slight ophryonic groove, fairly low receding forehead passing into the convex roof, and parieto-occipital region of practically hemispherical outline. An occipital torus as also receptacula cerebelli are difficult to distinguish. No interparietal groove is to be found while flattening over the asterion is very slight. The squamous suture is high and well rounded. The mastoid process is large but does not

entirely cover the digastric fossa. The tympanic ring and posterior zygomatic root are strongly built. There appears to be a slight inferior frontal eminence. General prognathism is common to the specimens.

In contour the frontal bone is curved, with median peaking. Prominent superciliarily ridges occur in company with an excavated supra-orbital triangle and but slightly projecting lateral processes. Orbital shape shows no consistent character, being low in one case and high in another. Whilst platyrhiny is found in all three, it is carried to an extreme in one case while the others approach the typical Negro range. Two skulls present a chamaeprosopic facial index, the third being mesoprosopic; here the subnasal region is moderate in size and corrugation. The infra-orbital region is hollowed out and lends prominence to the inferior lateral angle of the orbit.

Rounded occipital condyles are found with an elongated type of foramen magnum. The glenoid fossa is narrow and deep in one case, moderately shallow in another. The articular and post-glenoid tubercles are predominant. Variations in the digastric fossa are the deep, narrow and moderately shallow types. The palate is moderately broad to elongated, deep and fairly rugose. Anteriorly it is rounded, so that the palate is U-shaped. The interior of the vault displays well marked grooves for the meningeal arteries. In thickness the cranial bone is moderate or even massive.

DISCUSSION AND CONCLUSIONS.

Of the three groups into which this collection has been divided, the first apparently of some antiquity and displaying no Negro features, seemingly represents a prehistoric "Strandloping" population of this area. In the main, these skulls conform to what may be considered a distinctively Bushman type. The details in which they diverge from the Bushman type can be accounted for by some degree of admixture of the robust "Boskopoid" type, as demonstrated by Laing and Gear (1929) in the crania from the Zitzikama caves. However, these Port Elizabeth skulls, when compared with the Zitzikama specimens or with those from Knysna recently examined by Mr. D. F. Harris, approach more consistently to the slender Bushman type; only one skull (562A) displays the robust element to the extent seen in the Knysna and Zitzikama crania. This divergence emphasises the limitation of our present knowledge of these prehistoric coastal populations.

In the second and perhaps more recent group, we see a similar Bush-Boskopoid type infiltrated by Negro physical traits. Wells and Gear (1931) have shown how such infiltration

tion could extend far in advance of the limits of Negro colonisation. A tempting identification for this mixed population is afforded by the researches of Maingard (1931). He shows the area surrounding Port Elizabeth to have been occupied at the beginning of the historic period by two "Hottentot" tribes, the Damaqua and Damasonqua. Concerning these and other eastern Hottentot tribes, he notes that travellers of the period "all agree in noticing a series of differences between these and other Hottentots. They are taller and darker in complexion because of Bantu admixture." This is reinforced by philological evidence: "the etymology of *Damaqua* is assured. *Dama* means black . . . presumably because the eastern tribe was black or had a blackish tinge. The *Damasonqua* were probably a mixture of *Dama* and Bushmen (*Dama + sonqua*)."¹ Maingard has traced the disintegration and disappearance of these coastal tribes, members of which may very well be represented in the skulls before us.

The last and apparently latest group presumably represents the end of the process visualised by Maingard, the remnants of the Bush-Boskop type having been absorbed by the predominant Negro. At the close of the sequence we find the typical Negro and Eurafrikan individuals, who belong almost certainly within the period of the European settlement at Port Elizabeth.

This collection thus presents a physical demonstration of the successive changes in the indigenous population of the Port Elizabeth area from prehistoric to recent times. Its most curious feature lies in the appreciably different constitution of the pre-Negro group compared with similar remains from other coastal sites. This problem remains for future investigation.

My thanks are due to the Port Elizabeth and South African Museum authorities for placing the material at the disposal of the Witwatersrand University, to Professor R. A. Dart for his encouragement in this work, and finally to Dr. L. H. Wells for his constant practical assistance.

BIBLIOGRAPHY.

1. GALLOWAY, A.: The Skeletal Remains of Mapungubwe Camb. Univ. Press (1937).
2. LAING, G. D., AND GEAR, H. S.: A Final Report on the Strandlooper Skulls found at Zitzikama. This Journal, XXVI: 575-601 (1929).
3. MAINGARD, L. F.: The lost tribes of the Cape. This Journal, XXVIII: 487-504 (1931).
4. WELLS, L. H., AND GEAR, J. H.: Cave Dwellers of the Outeniqua Mountains. This Journal, XXVIII: 444-469 (1931).

TABLE I.: Chief Measurements and Indices of the Port Elizabeth Material.

Skull Number	Cranial Length	Cranial Width	Cranial Height	Frontal Width	Least Frontal Width	Porion- Breg- ma	Bi-Zygo- matic Diameter	Orbital Height	Orbital Width	Nasal Height	Nasal Width	Inter- Orbital Distance	Nasion Pros- thion	Nasion Symp- Menti	Basion Pros- thion	Basion Nasion
Group 1.	299	180.5	124.5	114.5	98.5	88	113	31.5	37.5	43	23	22	53	92	90.5	96
292	177.5	133	121	105	93.5	118	29	37.5	41	24	22	56	101	93	91	
580	176	127	113.5	96	86	116.5	31.5	36	38	29	22	51?	87	98	93	
S.A.M.																
1143	171.5	132	120	103	92.5	117	34	37.5	38	25.5	22	50	—	84	88	
293A	177	130	122	103	96	117?	31	37	42	28	25	53	98	94	93	
290	177.5	133	116.5	100	91.5	118	32	35	45	25?	27	59?	96?	—	94	
578	173.5	129.5	115	99	90	111?	—	—	—	—	23	—	—	—	—	—
562A	180	137	128?	111?	94	113	28.5	36	41	24	21	56.5	—	86	91	
Group 2																
296	174.5	140.5	125.5	106	97	127	30.5	36	42.5	24	21	57	96	100	99	
560	180	138	125	108	94	123	32	35.5	45	26	24	64	105.5	95	93	
582	178	131?	125	104	89	117	35	37	46	26	20	65	—	—	—	
321	179	140	—	—	84	—	—	—	—	—	20	—	—	—	—	—
290A	187?	141?	—	109	100?	—	—	—	—	—	21	—	—	—	—	—
293	164.5	123.5	—	100	82	—	28.5	36.5	42	26	23.5	—	—	—	—	—
Group 3																
304	183	136	129	111	97	130	34.5	42.5	51.5	27	24	68	—	—	102	
322	182	143.5	—	104	93.5	135?	31	36.5	44.5	31.5	31	67	—	—	100	
298	190.5	143	127.5	110	100	129.5	36.5	40?	47?	27.5	—	61?	—	—	101	

TABLE I.: Chief Measurements and Indices of the Port Elizabeth Material.

	Bi-Orbital Diameter	External Palatal Length	External Palatal Width	Internal Palatal Length	Internal Palatal Width	Cranial Index	Altitudinal Index	Verti- cal Index	Orbi- tal Index	U. Facial Index	Nasal Index	Pala- tal Index	Fr.- Pari- Index	Cranial Capacity
Group 1														
299	101.5	49 ?	57	38 ?	37	69	63.4	91.9	84	53.5	46.9?	124.1?	70.6	1118 c.cs.
292	104	54	65	42	42	74.9	68.1	90.9	77.3	58.5	47.4	120.4	70.3	1209 "
580	103.5	52	63	47	43	72.1	64.5	89.4	87.5	76.3	43.8	121.1	67.7	1088 "
S.A.M.														
1143	100	47.5	54	—	36	76.3	69.9	90.9	90.6	67.1	42.7	113.7	70	1180 "
293A	105.5	52	57	—	36	73.4	69	93.9	83.8	66.6	49.5?	109.6	73.8	1209 "
290	99	—	—	—	—	74.9	65.6	87.6	91.4	55.5?	50 ?	—	68.8	1193 "
578	98.5	—	—	—	—	74.6	66.2	88.8	—	—	—	—	69.5	1133 "
562A	99	49.5	59.5	42	37.5	76.1	71.1?	93.4?	79.1	58.5	50.0?	120.2	68.6	1346 "
Group 2														
296	105	50	59	44	37.5	80.5	71.9	89.3	84.7	56.4	44.8	118	69	1286 "
560	105	55	63	46.5	40	76.7	69.9	90.4	90.6	67.1	42.7	113.7	68.1	1350 "
582	99	52	56.5	—	35	73.6	70.2	95.4	94.6	56.5	55.5	108.6	68.4	1249 "
321	96	—	—	—	—	78.2	—	—	—	—	—	—	60	—
290A	102	—	—	—	—	75.4	—	—	—	—	—	—	70.9	1391 "
293	100	52 ?	57 ?	—	36 ?	75	—	—	79	61.9	—	109.6	66.4	1079 "
Group 3														
304	109.5	54	63	46	45	74.3	70.5	95	82.3	52.9	52.3	116.7	71.3	1361 "
322	111	57	66	44	43	78.8	—	—	85	70.1	49	115.8	65.1	1344 "
298	102	58.5	63	51	38.5	75	66.9	89.1	91.3?	58.5?	47.1	107.8	69.9	1482 "

All measurements are taken in millimetres.

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A PRELIMINARY COMPARATIVE STUDY OF SOME BUSHMAN AND STRANDLOPER CRANIAL SERIES

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INTRODUCTION.

Very few attempts have been made up to now to analyse and compare the physical composition of the diverse local groups of the South African Bushman people. The reason for this lies in the difficulty of assembling representative series of any such group, the scanty material available being dispersed through many collections.

In the last few years our Department has been singularly fortunate in having had loaned to it, at the same time, two of the most extensive collections of crania in this country, those of the South African and Port Elizabeth Museums. With these fine series to supplement our own material, a tentative approach to the problem of local variation in cranial type has become possible.

This present study embodies an analysis and comparison of three series of crania. Two of these, one from the South-Western area of the Kalahari and the other from South West Africa, represent two of the major subdivisions of the recent Bushman people. The third series consists of skulls from coastal sites in the vicinity of Knysna, C.P., and represents the so-called "Strandloper" population whose relationship to the true Bushman is still uncertain. Our system of analysis of these series follows as far as possible that used by Galloway (1937) for a South African Negro (Basuto) series.

THE SOUTHERN KALAHARI GROUP.

This group includes twelve adult skulls of which all but one belong to the South African Museum collection. All of these were collected in the region north of Upington. From the available data it appears that these individuals belonged to the same group of Bushman tribes whose modern representatives have been studied by Dart (1937). To them has been added one skull, recently obtained for our collection, of a member of Professor Dart's series.

The sex of all of these skulls is not recorded; a consideration of those in which it is known reveals the doubtful result of any attempt at sex differentiation on morphological features.

The majority of these skulls have an elongated brain case, seven being dolicho-cranial and one even hyperdolicho-cranial as against two mesati- and two brachy-cranial specimens. In comparison with the length, the height of the brain case is low or moderate, six skulls being chamaecranial, five orthocranial and only one hypsicranial. This relatively low height is even more sharply emphasised in comparison with the breadth; there being ten tapinocranial, only two metriocranial and no acrocranial skulls. All the skulls are micro-cephalic which emphasises their relatively small diameters.

In a vertical view the frontal region is of moderate breadth, the fronto-parietal index ranging from 67 to 81·2. The parietal bosses are usually infantile in development, there being eight examples of this as against two foetal and two adult forms. There are four ortho-ovoid and two chamae-ovoid skulls. Both brachycranial specimens also have infantile parietal bosses, one being hypsi-sphenoid and the other chamaesphenoid. Of the two specimens with foetal bosses, one is orthopentagonoid and the other chamaepentagonoid, while both skulls with adult bosses are chamae-ellipsoid.

In seven of the twelve skulls trigonism is present indicating that it is a common feature, while the interparietal groove is even more frequently present, appearing as it does in eight of the specimens. In eight of the skulls there is also post-coronal flattening.

The glabella is flat in eight specimens, slightly prominent in two and definitely prominent in two. In spite of this characteristic flatness of the glabella the ophryonic groove is present in seven cases.

A flat vault to the skull is characteristic in seven specimens, in one skull it is slightly convex and in four definitely convex. The vertex of the vault is situated at the bregma in eight cases, in front of the bregma in one and behind in three. There is no relationship however between the position of the vertex and the convexity of the vault. The parieto-occipital region is either inclined steeply (six specimens) or almost vertical (six specimens) and the nuchal plane faces downwards and backwards in eight cases and is horizontal in the remaining four.

Flattening of the supra-asterionic region is present in all except one of the skulls. In nine out of the twelve the parieto-temporal suture does not rise about the level of the pterion.

The mastoid process is small in seven cases (in two of

these it is extremely small), medium sized in three and large in only one specimen; while the supra-mastoid crest and groove are faint in seven skulls, moderately developed in three and strongly marked in only two. Three skulls have a prominent crest for attachment of sterno-mastoid, while in five specimens it is slight and in four completely absent.

In spite of the fact that the digastric fossa excavates the medial aspect of the mastoid process—as it does in ten specimens—in the majority of cases it extends posteriorly behind the mastoid process and is exposed from a lateral view.

In nine of the skulls the tympanic ring is slender; the foramen of Huschke is present in nine specimens. The posterior root of the zygoma is round in seven specimens and flat in four.

A mons-temporo-sphenoidale is characteristically present, being indicated in ten skulls. There is an inferior frontal eminence in eleven cases, in five of which, however, it is traversed by the anterior extremity of the superior temporal line.

As a rule, the face is orthognathous, this being the case in eight skulls. The upper facial index is usually mesoprosopic (six skulls) or chamaeprosopic (four skulls), the two remaining specimens being leptoprosopic.

The orbits are microseme in eight specimens, mesoseme in three, and megaseme in one. Thus the face is characteristically small, with low orbits which are usually quadrilateral, and in which the axis is usually oblique (seven specimens).

Usually the lateral supra-orbital triangle is excavated, this condition being seen in nine of the skulls. In only five cases is there evidence of auxiliary grooves or foramina for the supra-orbital nerves. The supra-orbital margin may be thick (seven cases) or thin (five cases), but both types are usually everted (ten specimens). In seven skulls there is an orbital shelf on the infero-lateral margin.

The malar region is angulated in nine of the skulls and a moderate to well marked infra-orbital fossa can be seen in seven skulls. The canine fossa while not as pronounced as the infra-orbital is also moderate to well marked in seven skulls.

The interorbital breadth is always relatively great; the nasal bones are flat in seven skulls and arched in four. In ten cases the nasal index is platyrhine, in one alone leptorrhine, and the nasal aperture is invariably trapezoidal in outline.

From a basal view nine skulls are seen to have an oval foramen magnum, and only two a circular one. The palate is usually shallow (eight cases) and smooth (seven cases). All those palates which are deep, are rugose as well. The majority of the palates also are "U" shaped. . . .

As a group these skulls present a mixture of Bush and Boskop features, the latter however predominating. Individual skulls also show Negro features to a varying degree, but this element is less pronounced and consistent than either of the others.

THE SOUTH-WEST AFRICAN GROUP.

Except for a couple of specimens of various but reliable origin, all of these twenty-two crania, whether in our departmental collection or that of the South African Museum, were obtained through Dr. L. Fourie. Their authenticity may therefore be taken as assured. For the same reason as in case of the Kalahari group, it has been necessary to treat these crania as a whole without discrimination of sex.

Of the twenty-two crania, fourteen are dolichocranial and eight mesatricranial. The height-length index, which could be determined in eighteen specimens, is orthocranial in eleven cases, as against six chamaecephals and only one hypsicephal. In relation to the breadth, the height is even more accentuated, all eighteen skulls being acrocephalic. Thus it is evident that the skulls of least height must also be the narrowest. Eight of these skulls are mesocephalic in capacity, the remainder of the group being microcephalic.

The fronto-parietal index ranges from 63·3 to 78·3, the average being 71·5.

The parietal bossing is foetal in seventeen of these skulls, infantile in the remaining five. Nine skulls are orthopen-tagonoid, five chamaepentagonoid and only one hypsipen-tagonoid, while there are two ortho-ovoid and two chamaeo-void; of the remainder three are pentagonoid and one ovoid.

The frontal region has characteristically a more rounded contour than the parietal, being foetal in only six cases, infantile in twelve and even adult in four. A metopic ridge is indicated in fifteen skulls. Post-coronal flattening is present in every specimen but one, while an interparietal groove is indicated in fifteen cases.

On *norma lateralis* the glabella is seen to be prominent in twelve, slightly projecting in seven and flat in only three cases. An ophryonic groove is present in eleven cases. The forehead is receding in ten whereas in twelve it is almost vertical. Of the twelve skulls which have low flat vaults half are highest at bregma and half behind porion, while the highest point of the ten convex vaults lie at bregma in six cases, and behind porion in four. The vault runs into a curved parietal region in fifteen cases, while in five the parieto-occipital region is an inclined plane of 45°. Sixteen occiputs are hemispherical in outline, only one vertical; the remaining two are missing. A flat nuchal plane is seen in eight skulls and a downwardly facing one in twelve specimens.

Supra-asterionic flattening is evident in all skulls but one, while the parieto-temporal suture is depressed in twelve cases and arched in ten. Variations in the size of the mastoid process are considerable, six being small while the remaining sixteen are of medium size. In the supra-mastoid region, the ridge for the attachment of the sterno-mastoid muscle is well developed in thirteen cases slightly developed in six, while in the remaining three it is absent. Wide shallow supra-mastoid grooves are found in sixteen specimens; in four they are narrow and shallow, while in two they are but faintly indicated. The supra-mastoid crest is a backward projection of the root of the zygoma in seventeen specimens, while in five it is continued backwards from the supra-auricular point. Of the digastric fossae, sixteen are exposed posteriorly at the expense of the base of the skull four excavate the medial aspect of the mastoid process while the remaining two excavate both the base and the process.

Three slender tympanic plates have been noted, as against twelve medium and seven massive ones. In fifteen specimens the posterior root of the zygoma is slender, and in six of moderate stoutness, while in one it is lacking. Two typical Bush characteristics, the mons temporo-sphenoidale and the inferior frontal eminence are both present in eighteen skulls; one has no mons and three no frontal eminence. Fourteen superior temporal lines are of Bush contour the remaining eight being Negroid.

Only four specimens show typical orthognathism, the other seventeen showing some degree of total and subnasal prognathism. The upper facial index is leptoprosopic in nine skulls, and chamaeprosopic in twelve. On norma facialis, peaking of the vault is evident in eleven cases, six are evenly rounded, while the remaining five have low flattened contours. Flattening of the supra-orbital triangle occurs in eight specimens only. In fifteen skulls there is evidence of grooving for the supra-orbital nerves, and in fourteen accessory supra-orbital foramina are present.

Of the orbits fifteen are microseme and three mesoseme, the remaining two being megaseme. The orbital axis is oblique in every orbit, except for one where this feature cannot be determined due to incompleteness of the bone. Slight eversion of the supra-orbital margins occurs in fourteen cases. A moderately wide inter-orbital breadth is seen in thirteen skulls, seven show very wide breadths, while only two are narrow.

The nasal index shows that fifteen skulls are platyrhine, four mesorhine and two leptorhine. Seven trapezoidal and fourteen pyriform nasal apertures are present. An indefinite inferior margin occurs in eight cases; in three it is rounded off, seven possess either a nasal gutter or sub-nasal fossa,

and the remaining three are limited by a sill. Slight excavation of the infra-orbital margin is found in nine cases, none at all in one, while the rest show well marked excavation. The canine fossa is present in varying degrees in seventeen cases, but is well defined in only three of them. Angulation of the malar region occurs in eight and the evenly convex type in thirteen specimens. Antero-laterally facing malar bodies are found in nineteen skulls, while two face laterally and almost vertically. Eighteen specimens show evidence of an orbital shelf.

When the skull is viewed in *norma basalis* the foramen magnum when present is usually oval (thirteen cases as against four which are circular). In ten cases the occipital condyles encroach on the area of the foramen magnum. Three maxillo-alveolar indices are dolicho-uranic, five mesuranic, and the remaining thirteen brachy-uranic. The palatal indices are brachy-staphyline in eleven, meso-staphyline in four and lepto-staphyline in seven cases. A divergent U-shape of the dental arcade is seen in six skulls, a horse-shoe shape in twelve and a broad U-shape in three skulls. Anterior shelving is present in sixteen palates; three only are smooth and four show evidence of a torus *palatinus*.

From this analysis it has been found that Bush, Boskop and Negro features are present in all the skulls. The former two types predominate so that all the specimens are of either Bush-Boskop, or Boskop-Bush character. In both, however, definite evidence of various degrees of Negro infiltration is provided by the consistent appearance of Negro features such as the hemispherical occiput, the vault having its highest point situated behind porion, the arched parieto-temporal suture, the evenly convex malar region, the divergent U-shaped palate. This series therefore represents an advanced phase in the process of infiltration of Negro features into the Bush-Boskop population.

For comparison with this series a group of four "Damara" skulls has also been examined. Whether these skulls are of Berg-Dama or Herero origin, they may be considered to represent the Negro neighbours of the Bush group studied. None of these skulls was in all respects typically Negro, all showing some admixture of Bush and Boskop features. However, this admixture was in no case so pronounced as to render these skulls indistinguishable from the Bush group.

THE KNYSNA GROUP.

Of the seventeen adult crania in this group, approximately half were removed from the caves of the Robberg peninsula (Peringuey 1908). The rest were derived from other coastal caves of the Knysna area, or from burial sites in the open. All, however, were associated with the same

coastal Late Stone Age cultural material. Three of the skulls belong to the collection of the Port Elizabeth Museum; all the remainder to that of the South African Museum.

The cranial index has a wide range of variation from 70 to 87. Within this range seven are dolicho-, six mesati-, three brachy- and one hyperbrachy-cranial. Thus while the majority of the brain cases tend to a moderately elongated form, a definitely broader element is also represented.

There is less variation in the auricular height index (56 to 64). Two skulls are chamae-, one hypsi- and the remainder ortho-cranial. While these specimens are thus of medium height relative to their length they tend to be low in proportion to their breadth—ten skulls being tapino- and the remainder metrio-cranial. This also reflects the tendency to a relatively broad type of skull.

Calculated by the Lee-Pearson formula, the cranial capacities range from 1175 cc to 1410 cc, one half of the skulls being micro- and the other half meso-cranial.

In a vertical view, the frontal region is consistently narrow. This is demonstrated by the fronto-parietal index which varies between 62 and 76, twelve specimens having an index below 70. It is worthy of note that this index is less than 70 in all the brachycranial skulls. The crania show typically foetal or infantile parietal bossings; it is to be observed that all the brachycranials have foetal parietal bossing. There are six pentagonoid crania of which two are chamae- and four orthopentagonoid, and four eurypentagonoid comprising three ortho- and one hypsieurypentagonoid. Of the seven skulls with infantile bosses, all are ortho-ovoid except one whose height index has not been determined.

The frontal bossing is foetal in ten cases and infantile in seven, the adult form not occurring. A distinct median (metopic) ridge in the frontal bone is present in no less than eleven cases. Post-coronal flattening is slight and only in three specimens do the flattened areas become confluent across the sagittal line. A slight depression between the parietal bones is usual but only in one skull is there an interparietal groove comparable with that seen in the Boskop skull. It must be stated that the skull which displays this feature is in general the most typically Bush specimen in the group.

In *norma lateralis* all the glabella show some slight projection over the nasion but there is a certain degree of variation from a very flat Bush to a more prominent Boskopoid type. Only one skull shows a well marked ophryonic groove. The low forehead is either vertical or receding. It curves sharply into a vault which may be either slightly curved, around a vertex at bregma, or flat but sloping upwards to a vertex behind porion. The curvature of the parieto-occipital

region shows many degrees of variation—abrupt and flat to moderately smooth and round. The occiput is either bulging and rounded or vertical and flat, while the nuchal plane displays a characteristic sigmoid contour.

At the asterion there is always some degree of supra-asterionic flattening. The parieto-temporal suture is usually slightly convex upward, thus rising above pterion but in six cases the anterior end is horizontal, and does not extend superiorly to pterion. Differences of obliquity in the posterior limb depend upon the height of the skull. The parieto-mastoid suture is usually horizontal.

In size and in shape, the mastoid process shows much variation. Two extreme types with many intermediate stages may be distinguished. On one hand, there is the small infantile type, on which the sterno-mastoid ridge is ill-defined; on the other hand, the large massive type on which the muscular attachment is better developed. The first type indicates the Bush strain, the second is produced by Boskop admixture.

An exposed digastric fossa is present in all the skulls except one in which the fossa is divided into two parts.

On examining the supra-mastoid crest, a gradual and progressive development from a faint to a well developed character is noted. The crest, which is the backward projection of the line of the zygoma, either curves up sharply or continues as a horizontal line. The supra-mastoid groove is continuous with the supra-asterionic flattening.

Foramina of Huschke may be present in a slender, Bush type tympanic ring, but never in the thick rugged plate, which characterises some of the specimens.

Although each skull possesses a mons temporo-sphenoidale, it is not a prominent feature. Only four calvaria exhibit a clearly defined inferior frontal eminence.

The course of the superior temporal line is so variable that it is impossible to give a general picture.

While the gnathic index, with a range from 94 to 96, and with one at 106, indicates that the vast majority of the specimens are orthognathous, it only gives a general idea of prognathism, and does not demonstrate the peculiar subnasal prognathism in this group. Five facial skeletons are markedly prognathous in the alveolar region, four show slight prognathism, three are entirely orthognathous.

The facial indices (42 to 53) show that the face is definitely broad and short. Ten are chamae-prosopic, and of these, three have indices below 45; two are mesoprosopic, and none leptoprosopic. The low cranial vault may be either evenly curved or flattened. Except for three skulls, the glabella and supra-ciliary arches are only faintly developed.

In thirteen cases the supra-orbital triangle is excavated. The fronto-biorbital index shows six values between 86 and 89, seven between 90 and 95, and three over 95 but under 97. This indicates that the external angular process of the frontal bone does not project laterally to any great extent; it is slender and of moderate size. The presence of auxiliary grooves and foramina for the supra-orbital nerves is the rule.

The quadrilateral orbit is either micro- or mesoseme-, ten being the former and two the latter. Of these twelve, four are chamae-, six ortho- and two hypsiconch. The indices vary between 70 and 88 and of these eight are below 79. Thus the eyes are very definitely Boskopoid, i.e. low and slitlike. An admixture with a high Bushman type is exemplified by the mesoseme orbits. The axis of the orbits may be either oblique (downwards and backwards) or transverse. Some signs of flattening are seen in the infero-lateral angle of the orbit but only two distinct orbital shelves are present. With one exception the interorbital breadth is not excessive. In a range from 17 to 26 for interorbital-biorbital index, eleven skulls are below 23.

The nasal indices (62 to 48) contain seven platy-, four meso- and one leptorhine. Relatively, broad and inflated nasal processes of the maxillae merge into a flat nasal bridge which may however be slightly arched. This flatness is due to the fact that the nasal bones are in one plane. Although the nasal aperture varies greatly in shape it tends to be wide and trapezoidal. The inferior margin of the nose is either round or it possesses a sharp sill. A slight subnasal gutter is present in four specimens. Prosthion-akanthion measurements tend to be small. In the infra-orbital region, there is little excavation and only four specimens possess a canine fossa.

The infero-lateral angle of the orbit is exaggerated by the maxillary process meeting the body of the zygoma in a sharp angle. The plane of the zygomatic body is not constant. It faces laterally but also slightly upwards and anteriorly.

Norma basalis shows an equal proportion of circular and oval foramina magna; of flattened, and of curved condyles. Circular foramina are not necessarily associated with either flattened or curved condyles—neither are oval foramina. Slight encroachment by the condyles on the anterior quadrants of the foramen is seen in seven of eleven skulls.

Although there is some degree of variation, the glenoid fossa conforms to a general pattern, broad and shallow with well defined articular and post-glenoid tubercles. The petrotympanic fissure is invariably exposed.

The maxillo-alveolar index (103-127) shows a wide variation, but it may be said to be brachyuranic since eight of the palates have indices over 115. The palatal indices also

show a wide variation (60-98) though eight of ten skulls lie between 70 and 86. The hard palate is therefore broad, U-shaped, and slightly rugosered. Two contain a slight torus palatinus, while three show some anterior tapering.

From this analysis it appears that almost all of the features shown are typical of either the slender Bush or the more robust Boskop type. Of a Negro element there is no obvious evidence. The whole group might therefore be regarded as the product of Bush-Boskop hybridization, the interpretation advanced by Laing and Gear (1929) for the closely comparable Zitzikama material.

A feature of the collection which demands explanation, however, is its wide range in cranial index from the dolichocranial to the hyperbrachycranial type. Since both the Bush and the Boskop crania are characteristically long or medium skulled, it is the broad type which has to be accounted for. Two explanations of this phenomenon have been advanced: one that it is a product of Bush-Boskop hybridization, the other postulating an alien—perhaps Mongoloid influence.

The hybridization mechanism was first suggested by Galloway (1935), who argued that a broad skull might result from the combination of the small Bush length with the large Boskop breadth. This concept has since been greatly elaborated on a genetic basis by Dreyer, Meiring and Hoffman (1938). It has the advantage that it does not involve postulating a further physical admixture on the evidence of one single cranial feature.

Wells and Gear (1931) argued for an alien, Mongoloid, intrusion in the Outeniqua cave material. They emphasise that this rests upon the combination of broad skulls with other alien features; brachycephaly alone is not in their opinion sufficient ground for such an inference.

Comparing the broad Knysna skulls with those of Mongoloid peoples, we have been unable to identify any unmistakeably alien features in these specimens. It is notable also that all brachycranial specimens from Knysna show foetal parietal bossing with the maximum cranial breadth high in the parietal region. In non-African brachycephals, foetal parietal bossing appears to be rare, and the maximum breadth tends to be lower down. The marked parietal bossing of the Knysna skulls is undoubtedly a pedomorphic character. If, as Dreyer, Meiring and Hoffman maintain, the pedomorphic factor is genetically independent of those controlling cranial diameters, hybridisation with a brachycranial type might increase the breadth of a pedomorphic skull without obliterating its foetal parietal bossing. The Knysna material does not however permit us to determine the mechanism involved in this case; the possibility of an alien element in this group must therefore remain unsettled.

DISCUSSION AND CONCLUSIONS.

On comparing these three groups of crania the following main points of difference emerge:—

The Knysna skulls are relatively broader and possess foetal rather than infantile frontal and parietal bossings. Furthermore, the fairly well marked interparietal groove which characterises the others is not present in this group. While the Knysna group and the South West African Bushmen tend to be ortho- and hypsi-cranial respectively the Kalahari calvaria are chamae-cranial. In comparison with their breadth the Knysna skulls are low, the South West African are high.

In lateral view the parieto-temporal suture does not rise above pterion in any of the Kalahari series but it may do so in the other two groups. Whereas the mastoid process is typically diminutive in the Kalahari group, it is of medium size in the South West African series; in the Knysna group it may be either large or small. A prominent supra-mastoid groove and a crest usually characterise a Knysna or South West African skull, but these are faint in Kalahari skulls. The tympanic ring which is consistently infantile in the Kalahari group may be thick and massive in the others. Knysna skulls are distinguished by the absence of an inferior frontal eminence, which is usually present among the inland Bushmen. While orthognathism is the rule among the Kalahari and Knysna groups, prognathism is found in the South West African series.

Facial view indicates the relatively longer faces of the Kalahari skulls and the absence of auxiliary grooves and foramina for the supra-orbital nerves in this group. Knysna crania show a rather sharp, non-everted superior orbital margin and a relatively narrow inter-orbital breadth as opposed to the everted supra-orbital margin and wide inter-orbital breadth of the other groups. Nasal apertures are characteristically pyriform in shape in South West Africans and trapezoidal in Kalahari Bushmen. The South Western group are characterised by a non-angulated malar region, the Knysna by the absence of orbital shelving.

While Knysna foramina magna are as often circular as oval, they are usually oval in the others. A horse-shoe palate predominates in the South West African skulls, a U-shape in the rest. Kalahari palates are relatively smoother.

There is a definite tendency to increased cranial capacity in the Knysna group.

Glabellae are most prominent in South West African calvaria. The ophryonic groove is absent from the Knysna skulls, whose vaults also tend to be more convex. In South

West African specimens the parieto-occipital region is round and not vertical as in the others.

These differences can be explained by the relative proportion of Boskop, Bush or Negro which each group contains. Thus the general massiveness of the Knysna material is produced by a predominance of Boskop features in a Boskop-Bush admixture which contains no Negro influences. The presence of a further alien, broad-headed type in this group remains problematical. In the more fragile Kalahari skull, Bush influences are more important and Negro admixture with the primitive stock is clearly indicated. Finally the South West African specimens have a larger proportion of Negro element than the others.

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BIBLIOGRAPHY.

- DART, R. A.: The physical characters of the auni—Khomani Bushmen *Bantu Studies*, 11, 175-246 (1937).
- DREYER, T. F., MERRING, A. J. D., AND HOFFMAN, A. C.: A comparison of the Boskop with other abnormal skull forms from South Africa. *Z. Rassenkunde*, 7, 289-296 (1938).
- GALLOWAY, A.: Some prehistoric skeletal remains from the Natal Coast. *Trans. Roy. Soc. S. Afr.*, 23, 277-295 (1935).
- GALLOWAY, A.: The skeletal remains from Mapungubwe. In: *Mapungubwe: ancient Bantu civilisation on the Limpopo* (ed. L. Fouche; Cambridge: University Press), 127-174 (1937).
- LAING, G. D., AND GEAR, H. S.: A final report on the Strandloper skulls found at Zitzikama. *This Journal*, 28, 575-601 (1929).
- PERINGUEY, L.: The Stone Ages of South Africa. *Ann. S. Afr. Mus.* 81-218 (1911).
- WELLS, L. H., AND GEAR, J. H.: Cave-dwellers of the Outeniqua Mountains. *This Journal*, 28, 444-69 (1931).

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REPORT ON TWO "KORANA" SKELETONS FROM BURIAL SITES NEAR UPINGTON

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With 1 Figure. Read 29th June, 1942.

The district north of the Orange River in the vicinity of Upington is known on the maps as Koranna Land and it is not surprising therefore that skeletons which are discovered in old graves from this region are classed as those of individuals belonging to the Korana tribe of the Hottentots. Two such skeletons were recently unearthed by a medical student, Mr. J. Wasserfall, in a locality known as No. 4 Cannon Island. The exhumation was done under permit by the Historical Monuments Commission and the skeletons were kindly handed over to the Anatomy Department. Cannon Island lies in the Orange River bed about twenty miles south-west of Upington. The skeletons had been found in separate graves each marked by a heap of stones, about 200 yards apart. Building operations were begun by a farmer and the sites had to be cleared rather hurriedly.

One grave contained the fairly complete skeleton of a young male adult. The other grave, perhaps the older of the two, contained a less complete and much more damaged skeleton of an elderly female. For purposes of this report the better preserved skeleton will be called No. 1, the other No. 2.

After clearing away the stones from the top of the graves and digging in gravelly soil, No. 1 skeleton was found at a depth of about 18 inches. No. 2 skeleton had been buried in soft sandy soil and was reached at a depth of about 30 inches. Both skeletons were lying on their right side with an east to west alignment, the head end pointing to the east. Mr. Wasserfall noticed a slight difference in orientation suggesting that one of the bodies had been buried in the summer and the other in the winter. In both bodies the limbs had been placed in a flexed position with one hand arranged between the knees and the other hand across the face. No funerary utensils or ornaments were found in the graves, although carefully looked for.

Method of Burial.—The method of burial resembled that figured in an illustration from a Report of an expedition to

collect old Hottentot skulls (Dreyer, 1937), with certain differences; e.g., in the photograph the left hand appears to be placed across the face, the right arm not being visible. In traditional accounts burial of the body in a sitting posture is given as an old Hottentot practice. The illustration figured in Dreyer's Report does not confirm this, nor was it the case with the two supposed Korana skeletons from Cannon Island. During an expedition to study Korana customs and language (Maingard, 1932) to which I shall have occasion to refer later, the older men were questioned on the subject of burial customs. It is specially emphasized that the practice of burying the dead in a sitting position was not mentioned by them.

SKELETON No. 1: MALE, AGED 20-25.

Cranium.—The skull is a little damaged. The right zygomatic arch is missing, and a small piece of the left zygomatic arch has broken away. When viewed from above the cranium has an elongated oval shape and is slightly phaenozygous. All the sutures are open indicating an individual less than thirty years old. The frontal bone is smooth and has no supra-orbital ridges. There are two sutural bones, one at the lambda and a second one in the centre of the right lambdoid suture. The spheno-basilar suture is not occluded, showing that the individual had not completed his 25th year.

The maximum length of the cranium is 186 mm., and it measures 128 mm. in breadth; this gives a cephalic index of 69, which puts it into the dolichocephalic class of skulls. The basion-bregma height is 139 mm., giving a height-length index of 74, that is orthocephalic. The height to breadth relationship of this skull expressed as an index gives the high figure of 108. The auricular height is 118 mm., and the cranial capacity 1375 cc.

Face.—The maximum bizygomatic diameter is 115 mm. and the nasion-prosthion measurement 64 mm. Basion-prosthion is 102 mm. and basion-nasion 103 mm., with a gnathic index below 100 or orthognathous. The mandible has a maximum length of 103 mm. and a maximum width of 112 mm. The orbital measurements are: height 32 mm., breadth 40 mm.

Teeth.—The teeth of the maxilla are in place, except the right third molar, two incisors on the right side and the left lateral incisor. The missing four teeth were probably present, having fallen out of deep healthy sockets. M_1 on the left side is smaller than the other two molars, but has reached the occlusal plane. The empty socket of M_1 on the right side also suggests a small wisdom tooth.

In the mandible all the molars, premolars, two canines and the right lateral incisor are in place; the other incisors are missing. The mandible is broken near the symphysis and the missing incisors have dropped out of healthy sockets. The two wisdom teeth are fully erupted and have reached the occlusal plane.

All the teeth are in perfect condition and the molars show a moderate degree of attrition.

The measurements of the skull show a closer resemblance to the Hottentot type than to either Negro or Bushman. It is dolichocephalic which is characteristic of the Hottentot skull, and distinguishes it from the broad-headed Bushman.

The skull is a comparatively high one with a basion-bregma measurement of 139 mm. The averages for the basion-bregma height in Hottentot males is given as 132 mm., and in the males of the Bushman type as 125 mm. by Drennan (1938). A height-breadth index of 108 differentiates this skull from that of a Bushman whose height-breadth index averages 91.

The mandible is of the strong Hottentot type, its maximum measurements being well above the averages given for Bushman males (mx. length 97; mx. breadth 110). The skull is mesocephalic with a cranial capacity of 1375 cc., against the microcephalic Bushman whose average cranial capacity is 1250 cc. The facial measurements show that the skull is orthognathous, as contrasted with the prognathous negro skull.

Upper Limb.—The right clavicle is 159 mm. long, the left clavicle 163 mm.; the left clavicle is very often longer than the right (Drennan, *Phys. Anthr.*). The right scapula is of a slender type; a piece near the superior angle including the root of the spine is broken away, thus making length and width measurements impossible. The left scapula is represented by a fragment which includes the inferior angle.

The right humerus is 328 mm. long; in the left humerus the head was missing and the bone could not be measured. Each humerus has a large supratrochlear foramen, but there are no supracondylar processes on either bone. The right ulna can not be measured because the head of the bone is broken off; the left ulna is 285 mm. long. The right radius is damaged, the left radius measures 270 mm.

The epiphyses of all the long bones had united to the shafts, indicating that the individual was more than twenty years old.

The wrist and hand bones are fragmentary: the carpal bones are represented by one scaphoid, one hamate, one trapezium and one pisiform. The metacarpus by a left first metacarpal, a right second metacarpal, and a right and left fifth metacarpal. There were six proximal phalanges among the bones and one middle phalanx.

Lower Limb and Pelvis.—The narrow sciatic notches and the small subpubic angle of the hip bones clearly point to the sex of the individual. The maximum height of the right hip bone is 203 mm., its maximum width 201 mm. The left hip bone is slightly damaged and does not allow measurements. The sacrum is damaged in its lower part, making measurements useless; the auricular surface of the sacro-iliac joint extends over the first, second and third sacral vertebrae, another characteristic pointing to the male sex.

In the right femur the lower end is missing; the left femur in its natural position gives a maximum length of 462 mm. The right tibia is damaged, the left measures 397 mm. The right fibula is 385 mm. long, the left one 382 mm.

As in the upper limb the epiphyses of the long bones are united to the shafts which indicates that the man was more than 20 years old.

The tarsal and metatarsal bones are fairly complete. The right calcaneum, talus, navicular, cuboid and medial cuneiform are present; also the left calcaneum, talus, navicular and three cuneiforms. All the ten metatarsal bones are represented, but four of them considerably damaged; and fourteen phalanges of the foot can be counted.

Other parts of the skeleton.—All the vertebrae are seen, also the sternum and the ribs, but many of the latter are considerably damaged.

The manubrium and body of the sternum are separate bones. The first and second pieces of the body of sternum are only partly united, confirming the previous estimate of the age of the individual. Union here takes place between puberty and the 25th year (Gray, 1938).

Stature.—The lengths of one humerus, one radius, one ulna, one femur, one tibia and of two fibulae are known. From this the cadaver length of the man can be calculated using the recognized Manouvrier's tables (Martin, 1928). As the length measurements of all six limb bones are available, it is best to take each stature reading separately and then to calculate the mean of the six results; the figure for the cadaver length obtained in this manner is 173 cm. In order to calculate the living stature one must subtract 1.26 cm. for a man and 2 cm. for a woman (Pearson, 1899). Thus we obtain a standing height for this male individual of 172 cm. (approx. 5 ft. 8 in.).

The average stature of the S.A. negro is given by Fritsch as 171.8 cm. The average stature of the male Hottentot is 161 cm., and that of males among Bushmen 156 cm. (Slome, 1929). To judge by stature alone, the skeleton would be called negroid. But the other data by which the individual is judged to be predominantly Hottentot are the more important ones, and he must have been a specially tall man among his tribe.

SKELETON No. 2: FEMALE, AGED ABOUT 60.

The second skeleton is the smaller of the two and the one which is much less well preserved. The skull is considerably damaged, only the left half being available. The line of breakage is to the right side of the median plane behind, so that about three-quarters of the occipital bone can be seen, and about one-quarter of the right parietal bone. In front, the line of breakage is to the left of the median plane and a portion of the left half of the frontal bone has disappeared. The facial skeleton presents a fairly intact left orbit and a maxilla of which pieces on the right side are missing. A reconstruction of the defective portion of the left half of the frontal bone was attempted, and the various measurements made on the half skull; but these must be looked upon as approximations. The sagittal and coronal sutures are totally closed; the lambdoid suture is totally closed in the portion near the lambda and in its middle part, but is still recognizable in the asteric portion. Using the information set out in a scheme of the suture segments of the vault with their time periods of disappearance (Drennan, 1939), the age of this individual would appear to be between 55 and 65. The piece of the base of the skull with the suture between the basisphenoid and the basioccipital is missing.

Cranial measurements.—When viewed from above the cranium is clearly phaenozygous. The maximum length of the cranium is 183 mm. and its maximum width 129 mm., with a cephalic index of 70 and therefore dolichocephalic. The basion-bragma height is 124 mm. with a breadth-height index of 37. The cranial capacity calculated by using the length, width and height measurements (Welcker Tables in R. Martin, 1928, is 1214 cc. The cranial capacity determined by the direct method, using the half skull lying on its side, gives the figure 1150 cc.

Measurement of the facial skeleton was impossible owing to the extensive damage to the bones.

Teeth and Mandible.—The upper teeth are all lost, except one second molar. The mandible is in two pieces: the left half is complete with a maximum length of 95 mm.; of the right half only the back portion is present with M_2 and M_3 in position. The right wisdom tooth is fully erupted, it has reached the occlusal plane and is practically the same size as the second molar. The molars show a much greater degree of attrition than those of skeleton No. 1, and the sockets from which teeth have been lost are a good deal shallower. Both these changes confirm the much greater age of the individual represented by skeleton No. 2.

The angle between the body of mandible and the ramus is 115 degrees against 110 degrees in the mandible of skeleton No. 1, and the slightly more obtuse angle may also indicate an age change. It is interesting to note that in this older individual the increase in size of the mandibular angle, usually associated with the loss of the teeth, appears to have occurred with the teeth still in situ, but considerably more worn down.

The shape and dimensions of the skull, especially the height-breadth index, suggest the Hottentot type. But there is an approximation towards Bushman characteristics, particularly the small cranial capacity; the average Bushman cranial capacity (male and female) is 1250 cc. The mean basion-bregma height for Hottentot and Bushman females is given as 123 mm. for both races by Hrdlicka. It is claimed that in the true Hottentot there are marked differences between male and female skulls, a feature also noted in the Oakhurst tribe (Drennan, 1938) which is becoming recognized as a very representative group of Hottentots (Schofield, 1942). If the two skeletons under discussion, buried so near each other and under identical conditions, belong to individuals of the same race, as may reasonably be expected, the marked difference between the male and female skull supports the claim made for a great sexual difference in this race.

Upper Limb.—The right clavicle is lost; the left clavicle measures 122 mm. The right scapula is represented by two small fragments; the left scapula is 121 mm. long, and 96 mm. wide.

Only the lower half of the right humerus is present and the trochlea of the left humerus has broken away. The left measured 274 mm. to the capitulum. By examining the lower end of the right bone it was determined that 6 mm. had to be added in order to allow for the missing trochlea; therefore the length of the left humerus is 280 mm. There are small suprtrochlear foramina in both the bones. The right ulna is 233 mm. long, the left ulna 231 mm. The right radius could not be measured as both upper and lower ends are broken off; the left radius is 212 mm. long.

The wrist and hand bones are very fragmentary, only six carpal bones were found, a scaphoid, lunate, triquetral, capitate, trapezium and hamate. Four metacarpals of the right hand were seen (first missing), and five metacarpals of the left hand.

Lower Limb and Pelvis.—The right hip bone is represented by its pubic part only, and the bone has a subpubic angle of 104 degrees which clearly indicates the female sex. This is confirmed by the wide sciatic notch on the left hip bone; in the latter the pubic part is missing. The maximum length of the hip bone is 172 mm. In the sacrum the right lateral mass is partly broken off; its length is 94 mm. The auricular surface of the sacro-iliac joint extends along the sides of the first and second sacral vertebrae only, another sign indicating the female sex; in the male the auricular surface spreads on to the third sacral vertebra (cf. skeleton of No. 1).

The right femur is 407 mm. long in its natural position; this is an approximation because the lateral condyle is broken off. In the left bone the head and neck are missing. Both tibiae are much damaged and could not be measured. The right fibula is lost; the left fibula is 339 mm. long.

As regards the tarsus we have on the right side: part of the calcaneum, talus, navicular and three cuneiforms; on the left side, calcaneum, talus, navicular, cuboid and the lateral cuneiform. All the ten metatarsal bones are there, the fifth left metatarsal damaged (distal end broken off). There are nine odd phalanges, eight proximal, one other.

Other parts of the skeleton.—Only fifteen vertebrae can be counted, many of them fragmentary, and only one half of the number of ribs are seen.

Stature.—This was calculated by the same method as in No. 1 skeleton, the lengths of the humerus, ulna and radius, femur and fibula being available. The figure for the cadaver length obtained from the tables for females (Martin, 1928) is 154 cm. To make an adjustment for living stature 2 cm. must be subtracted for a woman (Pearson, 1899), giving a standing height for this individual of 152 cm. (approx. 5 foot).

The average height of Hottentot women is given by Slomie (1929) as 149 cm. and the average height for females among the Bushmen as 147 cm. The females of the Oakhurst tribe (Hottentot) were 153 cm. tall (average of four individuals). The stature of this female skeleton therefore clearly suggests a Hottentot affinity. If this skeleton represents an individual of that race, then for the reasons already given, viz., close proximity of the graves, similar method of burial, skeleton No. 1 should also be looked upon as Hottentot, in spite of certain negroid characteristics.

HISTORICAL.

Maingard (1932) studied a small group of Korana living in Bloemhof on the Vaal River, a locality about 300 miles away from the Upington district. This group was a small remnant of the so-called Links Korana who wandered up the Orange and Vaal rivers in the course of the 19th century.

According to Professor Maingard the history of that branch of the Hottentots begins with their discovery on the Orange River by H. J. Wikar, an early historian, who lived among the tribe in the second half of the 18th century. Between Kakamas and Upington there is a stretch of the Orange River where it is about two miles in width and encircles numerous islands. This region in Wikar's days contained most of the Korana population, and it is from burial sites on one of these islands that the skeletons came.

In a recent paper Broom (1941) suggests that the Hottentots are a "hybrid race resulting from the crossing of Bushmen and Korana." His conception of the term "Korana" is, however, a very wide one. It embraces not only the living Korana clan of Hottentots, but many older prehistoric skulls usually referred to as Boskopoid on account of their having relatively large heads, approximating in size to that of the Boskop cranium. Exception must be taken to Broom's use of the term "Korana" in this generic sense. It must be emphasized that the relatively modern groups of Korana, as defined ethnologically, are already somewhat mixed, and appear to contain not only a Bushman element, but quite probably, to judge by their low cephalic index and the tallness of the male, a Bantu element as well.

The historical evidence is that the Korana mixed and intermarried with their Bantu and Bushman neighbours for as long as we have any record. But this admixture was apparently not sufficiently manifested in their external appearance to be commented upon till well on in the 19th century. The Korana are a vanishing tribe and it appears that not more than about one thousand exist now, scattered in small groups over the central portion of the Union (Maingard, 1932). They seem to have disappeared from the Upington district; at any rate the team of anthropologists, led by Professor Maingard, who studied the customs and language of the Korana in 1932, did not think it necessary to visit that region. The fact that the Korana are almost extinct is a strong reason for examining and recording any skeletal remains which are likely to be connected with them.

DISCUSSION AND CONCLUSION.

The anthropometric study of a small group of living Korana in Bloemhof showed measurements which were, on the whole, smaller than the Hottentot averages and resembled the "Bush" dimensions; e.g., the important measurement of auricular height gave an average of 116 mm. (eight males). In order to make a comparison with a skull measurement one must deduct 5 mm. to allow for the thickness of the scalp

(Martin, 1928). Thus we obtain 111 mm. for the Bloemhof group, a figure which may be contrasted with 118 mm. for auricular height in skeleton No. 1. Maingard makes the significant observation that the Links Korana living in Bloemhof, although historically Hottentots, anatomically are Bushmen. But as regards Negro admixture, there was hardly any trace in their physical characters, although from historical facts it is known that the Korana lived in close alliance with the Bechuana for many years; at any rate since the years 1778-9 when the tribe was studied by Wikar.

The following interesting explanation is given by Main-gard (1932). The Bechuana took Korana women for wives, but there is no proof that the Korana took Bechuana women for wives to any large extent. The children of a Bechuana father and a Korana mother were naturally incorporated within the Bantu tribe. Similarly the Korana took Bush women for wives and their offspring then belonged to the Korana. Thus the Negro heredity does not show itself in the Links Korana, while the "Bush" influence on their physical characters became more and more pronounced.

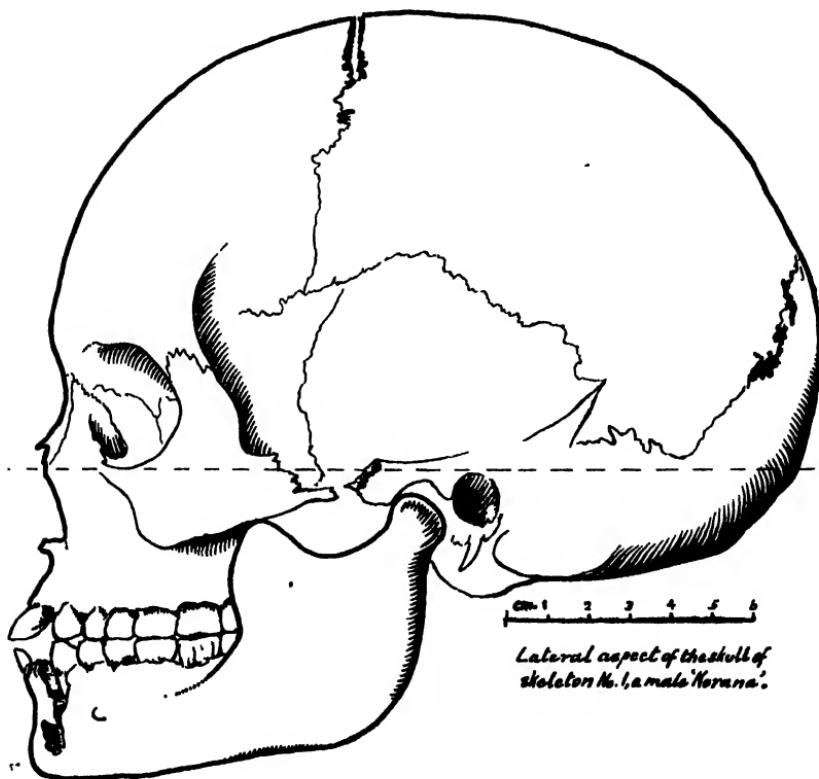
The two skeletons from Cannon Island in the Orange River near Upington which have been examined and measured are almost certainly Hottentot on anthropological grounds, with the reservation that the male skeleton (No. 1) may have some negro admixture. But one cannot go further than that. It is impossible to be absolutely certain about the evidence relating to skeletal characteristics, and the investigator of material from graves has to take certain premises on trust. There is no way of knowing the actual origin of such material unless the pre-burial history is accurately known. The Hottentot origin of the skeletons is supported by the historical and geographical evidence. These considerations, together with the additional evidence concerning methods of burial mentioned previously, are the reasons for assigning the two skeletons to a particular branch of the Hottentots, viz., the Korana. They differ from the living Bloemhof Korana by the fact that the "Bush" characteristics are less pronounced, and they conform very closely to the criteria now established for the Hottentot race.

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REFERENCES.

- BROOM, R.: *Annals of the Transvaal Museum*, 20, 220 (1941).
- DRENNAN, M. R.: *Trans. Roy. Soc. South Africa*, XXV, 279, 280 (1938).
- DRENNAN, M. R.: *Physical Anthropology*, Cape Town: The Mercantile Press, 30.

- DRENNAN, M. R.: The duration of life in the Bushman as determined by the suture closure of his skull. *Arch. Inst. Benj. Baptista*, Rio de Janeiro, V, 33 (1939).
- DREYER, T. F., AND MEIRING, A. J. D.: *Soölogiese Navorsing van die Nasionale Museum*, Bloemfontein, I, 81 (1937).
- GRAY'S ANATOMY: London: Longmans, Green & Co., 27th Ed. (1938), 232.
- MAINGARD, L. F., AND MAINGARD, J. F.: *Bantu Studies*, 6, 103, 163 (1932).
- MARTIN, R.: Lehrbuch der Anthropologie (1928), Bd. II, 1069, 646, 186.
- PEARSON, K.: On the reconstruction of the stature of prehistoric races. *Phil. Trans. Roy. Soc.*, London, 192, 187 (1899).
- SCHOFIELD, J. F.: *This Journal*, 38, 81, 90 (1942).
- SLOME, D.: *Annals South African Museum*, 24, 33 (1929).



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A PRELIMINARY STUDY OF THE POTTERY OF THE BANTU TRIBES OF THE UNION OF SOUTH AFRICA

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With 5 figures. Read 30th June, 1942.

INTRODUCTION.

For the purpose of this Study we have made the fullest use of Dr. N. J. van Warmelo's "Preliminary Survey of the Bantu Tribes of South Africa" from which we diverge because his Survey is based on political and linguistic grounds, while our Study neglects both of these aspects and attempts to classify the Bantu Tribes from the types of pottery which they make and use.

The following list shows how these classifications complement each other. It is to be noted that where van Warmelo uses the word "Division" we have used "Group" in the same sense.

- (1) The Nguni Group. Comprising the whole of the Nguni Division.
- (2) The Sotho Group. Comprising the whole of the Sotho Division, and such parts of the Tonga Division as have come under their influence.
- (3) The Venda Group. Comprising the Venda and Lembá Divisions.

THE NGUNI GROUP.

(A). ZULU POTTERY: The Native wares of Zululand are better known than any of the other pottery traditions of the Nguni Group, for they are well represented in our museums and are still made in large quantities, more particularly since the disuse of petrol tins has given a new impetus to the manufacture of pottery.

THE CLAY: The clay used is usually coarse and gritty. As it is obtained from the sides of water courses, it probably has a fair degree of temporary plasticity due to the presence of tannic acid which is derived from decaying vegetation.

METHOD OF MANUFACTURE: The exact method followed varies a good deal with different practitioners, small vessels are raised from the lump out of hand; larger vessels are always built up, either by the coil method, or by adding bats

of clay to the base which is usually started on a small mat, large pot-sherd, or other convenient object. After the pot has been shaped to the satisfaction of the potter, the exterior is scraped smooth and rubbed down with a piece of wet hide, and the pot is put in a cool shady spot to dry. When the clay has dried out the pot is rubbed over with a smooth pebble, and is ready for burning.

The burning takes place in the open without a semblance of a kiln, any available fuel is used, such as dried grass, cow dung or wood.

After cooling, the pots are treated with a compound made by mixing the pounded leaves of the *uVemvane* plant, (*Sida rhombifolia*), with sifted soot, this is rubbed into the surface and produces a fine black polish.

Pottery making is not undertaken during the winter months as it is thought that the cold, dry winds are likely to crack the pots.

As a result of the primitive methods of manufacture and firing, Zulu pottery is easily broken. Repairs are therefore frequent and are effected by drilling opposing holes on either side of a fracture, and then tying them together by passing string through the holes. The repair is rendered waterproof by a dressing of moist clay, which is renewed as often as may be necessary.

DECORATION: Zulu pottery is usually decorated with groups of pellets formed into rectangles, lines or crescents. The present practice is to roll small balls of clay between the palms and to press them into position on the pot wall while it is still green. In earlier times the pellets were attached by providing each one with a shank, which was taken right through the pot wall and buried over on the inside.

Another method of decoration is by means of parallel or crescentic wales of clay raised above the general surface of the pot. The use of the latter has suggested the eyebrows of a crude face to our potters, and with this many of the pots made for the curio trade are embellished.

It is interesting to note that these decorative methods are all derived directly from the decorative motifs used on the wooden meat dishes, milk pails, head rests, ladles, &cetera, the carving of which is exclusively the work of the men.

Pots are also decorated with loops and longitudinal lines formed with short stitch-like incisions, (1, 9).

In addition to these decorative methods, bands of chevrons are sometimes incised round the pot-mouth, or a belt of large chevrons may be run round the pot. Very occasionally roughly engraved designs are made on a pot after it has been burnt.

Mr. Denys Bowden of the Department of Mines noticed an old Zulu woman engaged on this work and asked her where

she obtained her designs. Holding up the iron bodkin which she was using she replied "Just as I pull this out of my hair, so they come out of my head."

It is to be noted that the comb is not used in the decoration of Zulu pottery.

POTTERY TYPES: The principal types of pottery in use are as follows:—

- (a) The *uKhamba* or drinking vessel. This is usually barrel shaped, about 7 inches in height and 6 inches over the rim, (1, 3).
- (b) The *umCakulo*, this is shaped like a pudding basin, it is used for eating food.
- (c) The *uPhiso*, this is a spherical pot with a short vertical neck. Usually it is from 8 to 12 inches in diameter. It is used for carrying beer and water, (1, 2 and 10).
- (d) The *imBiza*. This word is used for any large pot, but more particularly for the large spherical pots used in the brewing of beer. These may be as much as two feet in diameter, (1, 1).
- (e) The *iKhanzi*, this is a spherical pot with a wide mouth, it is about 9 inches in diameter and is used for cooking food. (1, 9 and 11).

Besides these common types there are other vessels which are probably used for special purposes. Amongst these we may include the *uPhiso* with four necks which is in the Durban Museum and the goblet on a tall pedestal in the museum at Mariannehill Monastery, (1, 4).

As far as we know Zulu pottery *always* has the flattened base.

(B). **LALA POTTERY:** The examples illustrated (1, 12 and 13), are from the collection in the Natal Government Museum, and appear to have been collected many years ago, in the neighbourhood of Table Mountain, which lies about 13 miles to the south east of Pietermaritzburg.

As might be anticipated, the ware is strikingly similar to Zulu pottery, but the decoration consists of impressions which were made either with a gouge or with the finger nail and which were arranged in lines and rectangles. In the finer vessels these impressions were filled in with a white pigment which contrasts with the black surface finish of the pot.

The types represented include the *uKhamba*, the spherical pot and the little pots with concave necks and a highly burnished bronze coloured surface finish. These last are (1, 13) of special interest, for if we are correct in attributing the highly decorated NC, pottery to the old Lala people, then these little pots may reproduce the ancestral wares on a small scale.

(C). **MPONDO POTTERY:** Pottery making in Pondoland appears to be dying out owing to the competition of cheap European products which the more affluent Pondos are able to purchase to a larger extent than the Zulus.

Their wares offer many points of similarity to those of the Zulus. The finish however is rather coarser. The decoration takes the form of patches of crescentic impressions (frequently made with the finger nails), disposed in I-shaped masses, loops or truncated triangles round the shoulder of the pot. The surface usually has a brown burnish.

The types used include:—

- (a) Barrel-shaped vessels, similar to the uKhamba, (1, 5).
- (b) Spherical pots with short flared necks, similar to the uPhiso, (1, 6).
- (c) Wide mouthed bowls with slightly everted rims, (1, 7).
- (d) Beer pots measuring 3 feet in diameter by 4 feet in depth.

All these types have flattened bases.

METHOD OF MANUFACTURE: Dr. Monica Hunter has given us a detailed account of Mpondo pot making in her "Reaction to Conquest." It is only necessary to state here that the processes are very similar to those in use in Zululand, but the pot is started with a ring of clay which is filled in with a flattened lump of clay to form the base. The walls are built up by adding successive rings of clay to the one surrounding the base.

Pottery is fired with wood, a slight depression is utilised and a secluded spot is chosen in order to avoid any danger from *intloko ethambileyo*, as a person with a soft head is called, whose presence would cause the pots to crack during firing.

(D). **THEMBU POTTERY:** Little has been recorded regarding Tembu pottery, save that the rims are decorated with notching (3).

(E). **XHOSA POTTERY:** Dr. Hewitt of the Albany Museum, Grahamstown, has informed the writer that Xhosa pottery is at present unobtainable as no more of it is being made. Up to the present no pottery from old Xosa sites has been described.

(F). **SWAZI POTTERY:** In Swaziland the potters' art is on the decline and it is not carried to the same degree of perfection as it is in Zululand, with the result that at the present time few well made pots are to be seen.

As is usual amongst the South-eastern Bantu, the women are the only potters, but the work is not restricted to particular families, for most women are capable of making their own rough domestic wares, although some women who develop a special ability in pot making, adopt it as a profession.

Where it is procurable, a special kind of black clay called *ibumba* is used for pot making. This is rolled into long cylinders, these are bent into circles and built up one over the other to form the pot wall which is then worked over with the hands to give a smooth surface; this is left a black or brown, but occasionally it is burnished. With this exception no decoration of any kind is used.

The commonest type is the simple spherical pot with a slightly flattened base, but occasionally one of these pots is to be seen with a short vertical neck. These are to be had in various sizes, but larger pots than about a gallon capacity are no longer made.

The burning is done on a dung fire in the open, or in the case of the better class of pots, in a hole in an ant hill.

We are unable to correlate these wares with the pottery which is made by the so-called "Swazi" immigrants in Sekhukhuneland which is quite distinct from all known Nguni pottery, for all their vessels have rounded bases and coloured surface decoration. This latter feature is certainly derived from the practices of the neighbouring Pedi potters, but the former is equally foreign to both the Sotho and Nguni traditions and may have had a Tonga origin.

From examples in the Durban Museum, it would seem that the Swazi have developed the making of wooden vessels to a greater degree of perfection than any other Nguni people. Not only are the milk pails decorated over the whole surface but large vessels for brewing beer were carved out of single blocks of wood.

(G). ANOTHER RELATED POTTERY TRADITION: On an open coastal dune site at Karridene, about 30 miles south of Durban, considerable quantities of a pottery, quite different to any described above, have been found, (1, 8).

This ware is in a blackened clay with a brown burnished or matt surface. Representative fragments of goblets and bowls have been taken. One of the latter had a foot, as distinct from a flattened base, and another had a rippled rim and a handle. A number of pieces of these handles were recovered from which it was seen that they had been attached by being taken right through the pot wall. Another fragment had a flattened boss which had been pierced with a small hole. A number of the fragments had been decorated with point marks and lines of fine cuneiform impressions which had either been made with a stylus or a roulette.

This pottery is precisely similar to a modern local ware, but we should not therefore dismiss it as being unworthy of our notice, for a pipe bowl, similarly decorated, was taken on the Dune Site at Durban North. As it showed every mark

of a considerable age, and as these pipes are no longer used in the district, it is probable that this pottery tradition is indigenous and is not a recent importation.

DISCUSSION.

The well known fact that amongst the Nguni all the pastoral work is restricted to the men and all the agricultural work to the women, is emphasized by our study of their pottery. This shows that the women have borrowed, and used on their pottery the decorative motifs proper to the wooden utensils of the men, who as representatives of the nomadic element of the community use that material in preference to clay.

This adaptation to clay of a decorative technique more suited to wood is unparalleled in South African ceramics and is all the more interesting because it was carried out by the more conservative sex. May we not have here a vestige of a migration of the Nguni people which was sufficiently protracted to foster a recrudescence of latent nomadic habits and the temporary abandonment of the pottery traditions. When these were resumed along with more settled living conditions, they appear to have been permanently influenced by the wood carving technique, which during a period of nomadism would tend to supplant pottery making.

Be this as it may, we believe that we are on strong grounds when we assert that of all the Nguni peoples, the Zulus have preserved their traditional culture more completely than any other, and that these traditions are reflected very clearly in their Pottery.

The political ascendancy of the Zulu has resulted in the imposition of their pottery traditions over a wide area of Natal where the Native peoples have abandoned their ancestral customs in favour of those of their powerful neighbour.

It will be seen from our illustrations that Nguni pottery is fundamentally simple in both its form and its decoration: indeed any exaggeration can be put down to European influence and the demands of the curio trade. Amongst such features we may enumerate the tall amphora-like vases, the use of rippled rims, and pots decorated with grotesque masks.

The use of white pigment, which we have noticed in Lala pottery may be an example of European influence, but on the other hand a similar practice has been found at Bambata Cave and in pottery from Haddon on the Limpopo, (4, p. 364 and 5, p. 47). We have also noted the possible affinities of the Karridepe wares, but the most striking example of a surviving influence from ancient times is provided by the wide mouthed Mpondo pots (1, 7) which resemble

very closely, the Class NC,^a pots with short flared necks both in general design and in the use of finger nail decoration (6, 2, 3).

We have already pointed out that the flattened base is one of the features which Nguni pottery shares with that of the Sotho. The goblets (1, 4), are doubtless related to those of Basutoland, but their ultimate origin must be very ancient, for they are obviously similar to the wooden cups which are made in Ovamboland.

THE SOTHO GROUP.

In the present state of our knowledge the pottery of the Sotho Division of the South Eastern Bantu peoples can be dealt with best by dividing it into three Sub-groups, namely those of the Basuto, the Tswana and the Pedi.

The first of these includes the pottery traditions practiced in Basutoland and those adjacent areas which are under its cultural influence. The second includes the pottery of the Tswana tribes living to the westward of the meridian of Pretoria. The third includes the traditions of the remainder of the Sotho people, of whom the Pedi are the principal representatives, with them we have associated the Tonga and Ndebele tribes which have come under their influence. It is by no means suggested that these Sub-groups are mutually exclusive, but rather that many of the tendencies which they have in common are more highly developed in one than in the others.

Owing to well known historical causes all three Sub-groups have many cultural affinities, which however are so confused that no adequate account of them has ever been attempted. In such circumstances our description of their pottery traditions must of necessity take the form of a recitation of isolated facts, which we trust will be of some small use to those who may follow us in this field of research.

(A). **BASUTO POTTERY: THE CLAY**—Generally, the clay used appears to be more carefully selected than is the case with the Nguni, and on the whole the pottery is of a much finer quality and finish.

DECORATION: The pottery is decorated by three principal means :—

- (1) By surface finish.
- (2) By designs engraved on the burnt pot. and/or incised with a point, stamped with a comb, bangle or other object on the wet clay.
- (3) By modelling.

(1) **Surface Finish**—A number of coloured surface finishes are employed of which the principal are, Deep red,

Light red, Brown, Yellow, Brindled buff, Black, Deep purple, (probably made with ox-blood) and Blue, the last a modern innovation. In addition to the coloured decoration, the better class vessels always have a fine glossy burnish.

(2) *Engraved, Incised and Impressed Decoration*—Engraved pottery is seldom found, and it may be that our example, (2, 12), illustrates the transference to another material, of a practice which is commonly used in the decoration of gourds and ostrich-egg water carriers.

Incised decoration is generally used in conjunction with comb or bangle impressions to form a band round the belly of a pot or a line of chevrons round its neck. The impressions thus made are occasionally filled in with a white or black pigment, (2, 11).

(3) *Modelling*—The outstanding examples of this form of decoration are the bird-shaped vessels, which will be dealt with later. In a lesser degree it enters into the design of many of the pots, more particularly the cups and smaller vessels, such as the bellied beakers, which frequently have projecting bosses or fancifully shaped handles.

It is hardly necessary to remark that all three methods of decoration are frequently to be found on the same vessel.

POTTERY TYPES: The principal types of pottery in use are the following:—

- (a) Cups, (2, 7 and 10) and Bellied Beakers, these are similar to (2, 7) but are without handles.
- (b) Goblets, (2, 5 and 6). . . .
- (c) Flasks, (2, 12) and Gourd-shaped vessels, (2, 11).
- (d) Bird-shaped vessels, (2, 3, 3 and 4).
- (e) Bi-conical pots, called *nkrō*, used in the making or storing of beer, (2, 1).
- (f) Cooking pots, called *letšexana*, (2, 8 and 9).
- (g) Cauldron-shaped pots, used for brewing beer, similar to (2, 8), but on a larger scale.

(a) The cups are found in a large variety of design and a great deal of care is lavished on their decoration. One of those illustrated, (2, 10), has a carinated profile, the ridge of which has been decorated with short vertical notches which appear to have been made with a file after the pot had been burnt.

The bellied beakers are small handleless drinking vessels, like the cups they show a great variety of design and decoration, and have a well marked protruding profile.

(b) The goblets have shorter pedestals than those of the Zulu. It is stated that they are used only by the boys.

(c) These types have a wide distribution. The gourd-shaped vessel illustrated, (2, 11), is finished with a brindled burnish and has the circular impressions of the chevrons with which it is decorated filled in with a white pigment. The flask, (2, 12) is an example of decoration with an engraved line on the burnt pot.

(d) The bird-shaped vessels are frequently made for the European curio trade, but we must not judge from this that the type is of recent introduction, for, one of those illustrated, (2, 2), was first published in 1900, (7, p. 89) before that trade had been developed, and another, (2, 4), shows such advanced stylism that a considerable antiquity is suggested for this type of vessel. A smaller but similar example in the Natal Government Museum has a stopper in the form of a fowl's head, which in contrast with the body of the pot is rendered in a completely naturalistic manner.

It is interesting to note that the only other recorded examples of zoomorphic pottery from South Africa, are the lion-shaped canopic vases used in the obsequies of their chiefs by some of the Zezuru tribes of Southern Rhodesia who practice the Mondoro cult, an animal-shaped pot found by MacIver at Niekerk, (8, p. 33), and the little bird in a polychrome ware from Vukwe in the Tati Reserve, which has such a strong resemblance to the soap-stone birds from Zimbabwe. (13)

(e) The bi-conical pots. It is probable that the peculiar shape of these pots was developed as a result of the process used in pot making, which may have been one in which the upper and the lower portions of the pot were formed separately and then welded together along the medial line. A similar origin is also suggested for the carinated pots.

(f) The Cooking pot, (2, 9), has something of the contour of the *nkxō*, which we may be certain is the result of fashion and is not due to any technical process. No. 8 is about a century old, and is really a small example of (g), it illustrates the conservatism of the Basuto potters, for its scolloped edge is precisely similar to those of its modern counterparts.

(g) Cauldron shaped pots for brewing beer. These pots are often of a very large size, one in the Natal Government Museum measures 23 inches in diameter and 36 inches in height. The edge of the rim is scolloped and just below it there is a wide thong of raw hide, which was cut from the skin in a circle and shrunk on to the neck of the pot as a reinforcement. A similar method is illustrated at (3, 1).

(B). TSWANA POTTERY: Much of what we have said regarding Basuto Pottery applies with equal force to that of the Tswana, which however has certain characteristics of its own which we will endeavour to set forth.

METHOD OF MANUFACTURE: The following account of pottery making at Mochudi, which is a Kgatla centre in the Bechuanaland Protectorate, was given to the writer by Dr. M. Wilman, the Director of the MacGregor Museum at Kimberley.

"First of all the woman put down a mat on which the pot was to be built up. She then mixed the clay and sand on a skin. Then she made a rectangular strip of clay about an inch in thickness; this she made into a circle to form the rim of the pot. Further strips of clay were added, and worked one on to the other, until the walls were bent over and were ready to receive the base. A flat piece of clay was prepared on to which the pot was reversed, and which was then worked in to form the base. The pot was then smoothed over and put in the shade to dry.

When it was dry it was put into a hole in the ground and burnt. After burning it was smoothed with a stone and burnished by another woman.

A large pot was sold by the woman who made it for a pound. She kept the money, only giving a shilling to her husband for carrying the pot to the store."

For repairing the breakages in their pots the Tswana use a gummy substance which they obtain from the "gif bol" (*Buphane disticha*). When it has set, the gum is black and very hard, it appears to be quite waterproof. The pot illustrated at (2, 12) has been repaired in this way.

DECORATION: Similar decorative methods are employed to those which we have noted amongst the Basuto, but modelling is not used to anything like the same extent.

The incised or impressed decoration usually takes the form of a bold band of chevrons round the neck or belly of the pot, (3, 2 and 5); which frequently approximates to the arcade motif of the Pedi, (3, 4).

POTTERY TYPES: The principal types of pottery in use are the following:—

- (a) Spherical and sub-spherical pots, (3, 2 and 5).
- (b) Carinated pots, (3, 4 and 5).
- (c) Cauldron-shaped pots for brewing beer, (3, 1).

(a) Spherical and Sub-spherical Pots. These types are used for cooking and for carrying and storing water. The body is usually depressed (3, 2) and may approach a lenticular section, for some have a distinct medial ridge. The neckless pots which are so common amongst the Zulu are seldom seen, for most of the Tswana pots have a short flared or concave neck with the rim cut square, the edges of which are sometimes decorated.

(b) and (c) The Carinated and Cauldron-shaped pots have already been dealt with under Basuto pottery (e) and (g).

(C). PEDI POTTERY: The predominant position which the Pedi have achieved has resulted in their pottery traditions being imposed on the Sotho tribes of the eastern half of the Transvaal, nor is their influence confined to these alone, for all the Bantu peoples with whom they have been associated show traces of the contact in varying degrees.

Many of the details of nomenclature and manufacture have been supplied by Mr. W. G. Barnard, and apply to Sekhukhuneland where the pottery industry is in the hands of Swazi immigrants who only came into the country about the year 1874. It is evident, that they have adopted the decorative motifs of the ruling caste, while at the same time they have retained their own pottery making technique. This "Swazi pottery" as it is called locally, appears to have largely replaced the older wares, which were much thicker and were finished with a buff surface.

THE CLAY: Generally the clay appears to be coarse, but over such a wide field of distribution it is evident that many types of clay must be used. The clay used in Sekhukhuneland is gritty and well burnt.

METHOD OF MANUFACTURE: In Sekhukhuneland, the clay is dug from pits by the women. It is then worked into small lumps, weighing about a quarter of a pound each. One of these is taken and rubbed between the palms of the hands until a roll of clay about 9 inches in length hangs down. This is taken and formed into a spiral coil which is to be the base of the pot. The walls are made by adding rolls which are built round the base, and scraped down to an even surface with a piece of a gourd. The unburnt pot is at this stage as soft and as pliable as a felt hat.

The pot is then moulded into its final shape, after which the decoration is added with a piece of wire or the finger nails. After this red ochre is rubbed over the body and graphite on to the decorated portions round the neck.

After drying, the pot is placed on three stones and covered with old grass which is surrounded with pieces of "Bobejaan Stert" (*Vellozia* Sp.), and burnt.

DECORATION: Typical Pedi pottery is decorated with a "comb" which is made from a piece of a gourd on the edge of which notches have been cut. With this tool the familiar "arcades" are easily made on the shoulders of the pots, (4, 2).

Almost equally common are the pots decorated with a wide band of lines and complementary triangles, all of which are impressed with a comb.

The bodies of these pots are usually burnished to a deep

red, with the triangles and other features picked out in a greenish black.

In Sekhukhuneland comb impressions do not appear to be used, as, doubtless owing to Swazi influence, they are replaced by incisions, but the characteristic arcades are still in evidence. On pots from this District, it is usual to find a line of deeply made incisions round the lip, and the neck decorated with a wide band of diagonal cross hatching. All of these are coloured with red, buff or graphite.

POTTERY TYPES: The principal types made are as follows:—

- (a) **Nkxô.** A large pot used for brewing beer, 16 inches in height and $15\frac{1}{2}$ inches over the rim, with a slightly contracted mouth. The ware is usually smooth and undecorated.
- (b) **Letsexa.** A barrel-shaped beer pot, 12 inches in height and 7 inches over the rim. It is usually undecorated.
- (c) **Pit  a.** A spherical pot with a slightly concave neck, of various sizes up to 10 inches in height and 12 inches over the rim. These pots are usually decorated as described above. They are used for holding water.
- (d) **Pitsana.** Small pots similar to the last but about $4\frac{1}{2}$ inches in height and 5 inches over the rim. They are used for cooking spinach.
- (e) **Morufsi.** Bowls, these are in various sizes, up to 6 inches in height and 18 inches over the rim. They are usually decorated with a band of diagonal cross hatching below the rim.
- (f) **Morufsani.** Platters, 3 inches in height and 8 inches over the rib. Usually undecorated.
- (g) A spherical pot, with or without a short flared neck. They are as much as 14 inches in height and 15 inches in diameter and decorated with polychrome bands.
- (h) Similar to the last, but with a wider mouth. It is about 11 inches in height, 13 inches in diameter and 11 inches over the rim.

In addition to these there are a number of other vessels, such as vases, jugs, three legged pots, (4, 5), and tumbler-shaped drinking pots, (4, 3). It is probable that all of these owe their inspiration to some degree of European influence, although they may represent ancestral types. There is for example, a three-legged bowl in the Transvaal Museum which belonged to Chief Mapiela of the Langa clan of the Ndebele.

who died in 1825, and the drinking pots are very similar in shape to the tumbler beakers from Bambandyanalo in the Limpopo valley.

Generally speaking the majority of the Pedi pottery follows the example of the Nguni, Basuto and Tswana, in having flattened bases. In Sekhukhuneland however, all the pots have rounded bases, due doubtless to the "Swazi" influence which we have previously noted.

DISCUSSION.

From the foregoing, we believe that we are justified in drawing the conclusion that modern Sotho pottery represents the convergence of two traditions, which, whatever their origin may have been, had in the past run on separate courses for a considerable period of time. We suggest that these traditions are at present represented respectively by Basuto and Pedi pottery, with the Tswana wares occupying an intermediate position.

If this is indeed the case it would be reasonable to assume that an analysis of the characteristics of Basuto and Pedi pottery should provide us with the means of identifying the wares of the original pottery traditions, should they be unearthed on an archaeological site.

This surmise has much to support it in respect to Pedi pottery, for we believe that we are on strong ground in suggesting that the prototype of the arcade motif is to be found in the heavy chevrons which were used to decorate the better finished pots from the Aasvoëlkop site near Johannesburg, more particularly since both colour and comb were used in their decoration. Further there can be little doubt but that this Aasvoëlkop pottery is intimately connected with the oldest pottery from the sites of Gokomere and Zimbabwe, which Caton-Thompson called "Class A," (9), and for which we have suggested the symbol R₁ should be used (10). These wares we believe to have been made by the pre-Sotho inhabitants of Southern Rhodesia.

We have no suggestions to offer regarding the antecedents of Basuto pottery, for the great variety of the types made, and the facility with which even foreign wares are imitated, indicates that we are dealing with potters whose unusual initiative and fertility of resource could hardly be bound by tribal customs. We must expect that in the past as in the present, rapid changes in both design and decoration have taken place, and it is therefore impossible at the present time to link Basuto pottery with any of the pre-historic wares.

The carinated profile which is characteristic of the Tswana wares is certainly of a considerable antiquity, for its

occurrence has been recorded from such widely separated sites as Mumbwa, Toupye, Parma, Mapungubwe, Gokomere and Cathkin Peak. It is probable that this feature is to be associated with some form of the "two-piece" method of pottery manufacture, and it is interesting to find this method still in use amongst the Tswana.

The decorated rims and the profile of such specimens as 3, 5 appear to serve as links between the modern Tswana wares and those from the old sites of the Zeerust district, (11). These last are probably connected with the Class NC_a pottery from the coastal sites of Natal and ultimately with such pieces of Mpondo pottery as that illustrated at 1, 7.

THE VENDA GROUP.

At the present time the Venda occupy the north-eastern corner of the Transvaal, where they have preserved their ancestral customs in a greater degree of purity than has been achieved by any other Native people of the Union of South Africa. They are moreover the latest Bantu arrivals in our Country, for in accordance with their traditional history, the truth of which there is no reason to doubt, their ancestors crossed the Limpopo River on their southward march, only about two hundred years ago.

THE CLAY: The clay is dug at spots where experience has shown that good pot earth can be obtained. No evidence has been recorded of the tempering of the clay by the addition of sand or of any other material.

METHOD OF MANUFACTURE: The following is an account of the pottery work as it is carried on at Mphephu's village near Louis Trichardt, in the Northern Transvaal, where all pot making is done by women of the Lemba people.

The woman took a lump of clay which was about the size of her two fists, placed it upon a piece of potsherd and proceeded to knead it into a rough saucer-shape. She then worked the clay out of the centre to form the walls of the pot with her left hand.

With the potsherd as a fulcrum, she then revolved the growing pot from left to right, and at the same time she smoothed its outside with a triangular piece of horn. During the process she continually moistened both the horn and her hands in a small pot of water which she kept by her for that purpose and for holding her various tools.

These horn tools are about 3 inches in length and 1½ inches in width, all the angles being rounded off. In those used on the outside of the pot the long side is slightly concave, while for those used on the inside of the pot, it is slightly convex.

When the pot wall had been raised to its required height, more clay was added in the shape of a roughly rectangular slab, in order to bring in the top of the pot to its central opening.

This done, the interior of the pot was smoothed off with a convex tool which was carefully selected to suit the size of the pot.

The next operation was to nip off, between the thumb and the index finger, the surplus clay from the lip of the central opening. The lip was then turned up slightly, undercut on the outside with the concave tool, and finished off by being rubbed with a piece of soft leather which had been soaked in water.

The body of the pot, which was about 8 inches in diameter, was now complete. The decoration, which consisted of two incised lines, was then put on by holding a large thorn against the shoulder of the pot and slowly rotating it, a few lines of hatching were added and the first stage in the making of the pot was complete, the whole process having taken about a quarter of an hour.

The pot was then put aside to dry, after which the colour finish, consisting of red ochre and graphite was rubbed into the surface. The burning was done with wood fuel in the open, without any attempt to make a kiln.

DECORATION: The pottery is decorated with colour and with incised lines, generally in combination. The colours used are, deep red, light red, buff, black, and graphite.

POTTERY TYPES: The principal types of pottery in use are as follows:—

- (a) Cups. The one illustrated, (5, 4) belonged to Chief Mphephu. The conical base is hollow and burnished with graphite.
- (b) Spherical Pots. These may be up to 2 feet in diameter. The mouth is finished with a bold roll, round the shoulder there is a narrow band of herring-bone incisions, and the surface has a matt self-coloured finish. These pots are used for brewing beer, holding water and storage.
- (c) Small Spherical pots. From 5 to 12 inches in diameter. (5, 3). The larger of these may have short vertical necks. They are decorated with wide bands of chevrons or triangles in contrasted colours with a fine burnished surface. The larger of these are used for serving beer and the smaller for drinking water.

Gourd-shaped Pots. These may be as much as 14 inches in height by 12 inches in diameter. The mouth is finished with a bold roll. The whole body is decorated with longitudinal strips, alternately red and graphite, finished to a fine burnish. They are used for storage and for carrying water, (5, 5).

Bowls. These frequently have the pedestal base, they are used as platters and as covers for storage pots.

Graters called *Mugurudo*. These hemispherical bowls, about 6 inches in diameter, have the whole of the inner surface deeply scored. They are used as mortars for grinding snuff. For this purpose a small dumb-bell-shaped pestle is used.

DISCUSSION.

From the pottery found on the old Venda sites of Dzata, Verdun, Haddon and Maryland, we know that at one time it was identical with the Rozwi wares from such well known sites as Zimbabwe, Dhlo-Dhlo, Nanatali and Khaini, which Caton-Thompson called Class D, and for which we have suggested the symbol R_s. Thus we can fairly consider our Venda pottery as being a representative of these bygone glories, nor is there any doubt but that the Venda of an earlier generation were intimately associated with the builders of the Rhodesian Ruins. Nor is the resemblance confined to the finer polychrome wares, for the large spherical pots seem to be very similar to the brown sherds described by Caton-Thompson as Class C' pottery at Zimbabwe.

Scattered amongst the Venda there are small communities of Lemba. These people have no political organization, and live on terms of easy symbiosis with their Venda over-lords, for whom they work as craftsmen, receiving agricultural products in exchange for their work. In such circumstances it is only natural to find that Lemba women are the potters. We shall nevertheless refer to their wares as being Venda Pottery.

We have no knowledge as to how or when this condition arose, nor do we know the effect which it has had on Venda pottery, nor if the Lemba ever had a pottery tradition of their own, or draw their inspiration from the people with whom they live.

It will be seen that both the Sotho and the Venda decorate their wares with coloured surface finishes. It would be natural therefore to assume that both had arisen at the same source. Although this may ultimately prove to have been the case, yet we believe that each has flowed in a widely divergent channel for so many generations, that at present we may regard them as being quite distinct. In support of this conclusion we would instance the facts that the use of the comb although typical of much Sotho pottery is unknown in Vendaland, while the Venda practice of using a potsherd to form a primitive turn-table on which the pots are moulded, is unknown amongst the Pedi.

GENERAL CONCLUSIONS.

From the foregoing we believe that we can conclude that:—

The present day pottery traditions of the Bantu inhabitants of the Union of South Africa can be classified on lines which coincide closely with the linguistic divisions, and are as follows:—

(a) Nguni Pottery which includes the traditions of the Zulu, Mpondo, Thembu, and the Swazi peoples.

This Group is distinguished chiefly by smooth surfaces with panels of closely set decoration. Amongst the Zulu these panels are formed with incisions, projecting ridges, wales and bosses, which can be shown to be derived directly from the carved motifs of their wooden utensils. The bases are flattened and a black surface finish is used.

The repertoire is very limited, consisting chiefly of spherical vessels (with and without necks), basins and barrel-shaped pots.

The wide-mouthed pots made by the Mpondo are clearly connected with the NC₂^a pots found on the coastal sites of Natal, which in turn seem to be related to the old Huruthse wares from the Zeerust district of the Western Transvaal.

In Natal the political and military predominance of the Zulu has resulted in the obliteration of many pottery traditions, traces of these may be found in the Lala pottery from the Pietermaritzburg district, or in the fragments from Karridene.

(b) Sotho Pottery, which can be further classified as Basuto, Tswana and Pedi.

All of these industries are intimately connected, but each has characteristics of its own. Of these the Basuto and the Pedi show the greatest divergence, while the Tswana occupy an intermediate position. All however make use of polychrome surface decoration and generally use the flattened base.

Basuto Pottery. These wares display a very fine technique, and great originality of design which has its culmination in the bird-shaped pots. The surface is frequently finished with a fine burnish, brindled buff and deep red predominating, but many other colours are used.

The form of the large pots approaches a bi-conical section, the carinated section and comb decoration are of uncommon occurrence, the place of the latter being taken by bangle impressions.

Tswana Pottery. These wares have much in common with the Basuto wares, but the bird-shaped pots are absent. The carinated and sub-spherical sections are common and sometimes combined with the arcade motif and comb

decoration. This pottery may also be connected with the old Huruthse wares.

Pedi Pottery. The outstanding characteristics of the Pedi wares are the use of comb stamped decoration and the arcade motif. The political predominance of the Pedi has made these factors of common occurrence over the eastern half of the Transvaal, with the result that other traditions, such as that of the immigrant Swazi, have tended to become absorbed.

We have suggested that two ancient traditions are represented in modern Basuto and Pedi pottery. Regarding the antecedents of the former nothing is known, but those of the latter can be linked with one of the earliest potteries from the Southern Rhodesian sites. It was called Class A pottery by Caton-Thompson, who recognised it at Zimbabwe, Dhlo-Dhlo and Gokomere. We have suggested that the symbol R₁ should be used in describing this pottery, which we believe was made by the Pre-Sotho inhabitants of Southern Rhodesia.

(c) Venda Pottery. This pottery also includes richly coloured wares. Apparently the comb and the arcade motif are not used in the decoration, which usually consists of triangles and/or chevrons in contrasted colours, separated by incised lines. Usually the pots have rounded bases but the flattened base is found occasionally.

This ware is derived from those potteries from the Southern Rhodesian sites which Caton-Thompson described as Class D, and for which we have suggested the symbol R₃. This R₃ ware was made by the Rozwi who were the paramount people of Southern Rhodesia during the 18th and the earlier part of the 19th centuries.

We find that we cannot lay down any definite rules regarding the technique followed in the building up of our pottery, for it seems to be entirely a matter of convenience or of individual choice as to whether the pots are raised from the lump, or built up with bats, coils or rings. Thus Mrs. Martin has recorded that in the same Manyika family, one woman made her pots with bats of clay, while another used the coil technique (12).

Regarding the ways in which the pots are formed, we find that there are two well marked methods in use in our Area.

- (a) In which the pot is constructed upwards from the base. (Nguni, Pedi and Venda).
- (b) In which the body of the pot is built upwards from the mouth, the base being formed separately and added afterwards, (Tswana).

In addition to these, two other methods have been recorded.

- (c) In which the upper part of the body is built upwards towards the mouth, the base being formed subsequently. (*Manyika*, 12).
- (d) In which the body was built upwards to the base, the neck and lip being formed subsequently. (*Hottentot*).

It is at present uncertain how far these methods represent ancestral practices, but it is very probable that some similar method to that used by the Tswana, gave rise to the carinated profile, which is one of the representative features of the old pre-Sotho pottery.

We also noted that with the exception of the wares of Sekhukhuneland and Vendaland, the flattened base is universally used by the Bantu potters of the Union. Nor is there any probability that the practice has grown up as a result of the European Occupation, for similar bases to those which are made to-day have been found on archaeological sites at Mapungubwe and on the coastal sites of Natal.

Although the wheel is unknown to the Bantu, the majority of them have adopted the use of a mat which enables the potter to turn the work about to suit her convenience. This idea has been carried still further amongst the Venda, who by starting the work in an old pot-sherd, have developed a simple type of furn-table.

ACKNOWLEDGMENTS.

Our thanks are due to Dr. N. J. van Warmelo for the very great assistance which he has given us in the preparation of this paper.

REFERENCES.

- (1) VAN WARMELLO, N. J.: A Preliminary Survey of the Bantu Tribes of South Africa. The Government Printer, Pretoria (1935).
- (2) HUNTER, MONILA: Reaction to Conquest, p. 100.
- (3) LAIDHER, P. W.: The Bantu Potting Industry and its impacts on other Native Potting Industries in South Africa. This Journal, **xxix**: 789 (1932).
- (4) SCHOFIELD, J. F.: A Report on the Pottery from the Bambata Cave. This Journal, **xxxvii**: 361-372 (1940).
- (5) FORCHÉ, LEO: Mapungubwe. Ancient Bantu Civilization on the Limpopo. Cambridge (1937).
- (6) SCHOFIELD, J. F.: Natal Coastal Pottery from the Durban District. This Journal. **xxxiii**: 993-1009 (1936).
- (7) CHRISTOL, F.: Au Sud de l'Afrique. Paris, 1900.
- (8) RANDALL-MACIVER, D.: Mediaeval Rhodesia, London, 1906.
- (9) CATON-THOMPSON, G.: Zimbabwe Culture. Oxford, 1931.
- (10) SCHOFIELD, J. F.: A Survey of the Recent Archaeology of Southern Rhodesia. This Journal. **xxxviii**: 81-111 (1941).

- (11) VAN HOEPEN, I.: Argeologiese Navorsing van die Nasionale Museum, Bloemfontein, vol. ii, pt. 1.
- (12) MARTIN, C.: Manyika Pottery. This Journal. xxxvii: 350-360 (1940).
- (13) FROBENIUS, LEO: Erythräa. Atlantis-Verlag, Berlin, 1931. Plate 50.

ILLUSTRATIONS.

Text Figure No. 1. Nguni Pottery.

- (1) *imBiza*. Finished with a black burnish and decorated with pellets. Probably from Cetewayo's Kraal. Durban Museum.
- (2) *uPhiso*. Finished with a black burnish. As above.
- (3) *uKhamba*. Finished with a black burnish and decorated with horizontal wales. As above.
- (4) ▲ Goblet. Finished to a black matt surface and decorated with nail-heads raised from the clay of the pot. From Zululand. Mariannhill Monastery. Pinetown, Natal.
- (5) *iNgay*. In a coarse ware with a brown matt surface and decorated with finger-nail impressions. From Pondoland. South African Museum, Cape Town.
- (6) *inKongo*. Decorated with finger-nail impressions, finished to a red matt surface with the decorated areas blackened. From Pondoland. East London Museum.
- (7) *inKongo*. Decorated with oat-shaped impressions. As last.
- (8) A bowl in Karridene ware. Decorated with roulette or stylus impressions and finished with a brown burnish.
- (9) *iKhanzi*. Finished with a black matt surface and decorated with short stitch-like impressions. From Zululand. Natal Government Museum.
- (10) *uPhiso*. Finished with a fine black burnish and decorated with triangular wales. From Zululand. Natal Government Museum.
- (11) *iKhanzi*. As last.
- (12) *uKhamba*. In a rough black ware decorated with deep rounded impressions filled in with white pigment. Lala pottery from table Mountain district Pietermaritzburg. Natal Government Museum.
- (13) Small pot with a fine bronze burnish and decorated with crescentic impressions. Lala pottery. As last.

Text Figure No. 2. Basuto Pottery.

- (1) *Nkrū*. Finished with a deep red burnish with large black triangles below the rim. From Maseru, Basutoland. Natal Government Museum.
- (2) Bird-shaped pot. From Au Sud de l'Afrique, p. 89. Not drawn to scale.
- (3) Bird-shaped pot, with a red burnished surface. From Basutoland. The MacGregor Memorial Museum, Kimberley.
- (4) Bird-shaped pot, with a brindled burnished surface. From Basutoland. Durban Museum.
- (5) Goblet in a black burnished ware. From Basutoland. Transvaal Museum. No. 35/140.
- (6) Goblet, with a yellow burnish, decorated with comb impressions filled in with white pigment. From Basutoland Mariannhill Monastery. Pinetown, Natal.
- (7) Double handled cup. In burnished polychrome ware. From Basutoland. The MacGregor Memorial Museum, Kimberley.
- (8) *Letšexana*. In a rough brindled clay. From Basutoland. Natal Government Museum
- (9) *Letšexana*. In a brindled buff burnished ware. As last.
- (10) Cup, with a single handle and a carinated profile. In polychrome ware. As last.

- (11) Gourd-shape pot. In a ware with a brindled burnish. The impressions of the lines of the chevrons were made on the wet clay and filled in with white pigment. Mariannhill Monastery, Pinetown, Natal.
- (12) Flask. In a burnished polychrome ware with engraved line decoration. From Basutoland. The MacGregor Memorial Museum, Kimberley.

Text Figure No. 3. Tswana Pottery.

- (1) Beer pot, with a flat base, 9 inches across. In a coarse red ware. This rim was rounded, slightly everted and decorated with vertical notches, below it a rimpie band had been shrunk on. From Mochudi. The MacGregor Memorial Museum, Kimberley.
- (2) A sub-spherical pot with a short flared neck, in a highly decorated red ware with a burnished surface. The MacGregor Memorial Museum, Kimberley.
- (3) A spherical pot with a short flared neck and a flattened base, finished with a brindled burnish and decorated with a band of irregular chevrons round the shoulder. From Molepolole. The MacGregor Memorial Museum, Kimberley.
- (4) A large carinated pot, in a polychrome ware with raised bands and a highly decorated arcade. Modern Huruthse. Nasionale Museum, Bloemfontein.
- (5) A carinated pot, with a flattened base, in a dark brindled ware. Southern Tswana. The MacGregor Memorial Museum, Kimberley.

Text Figure No. 4. Pedi Pottery.

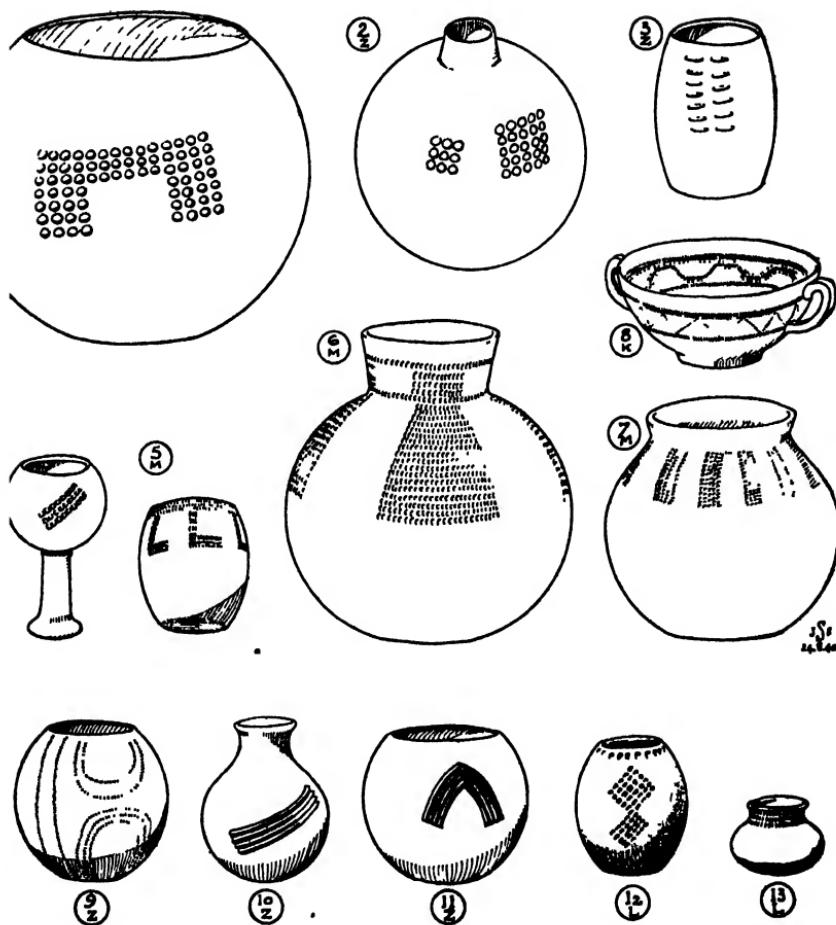
- (1) *Pitsa*, with a flattened base, in a red burnished ware with a polychrome band round the neck, the lines of which were made with a comb. From the Pretoria district.
- (2) *Pitsa*, similar to the last, but with an arcaded band.
- (3) Tumbler with a floral motif in greenish black on a red ground. From the Lydenburg district.
- (4) *Pitsa*, in a fine gritty clay, finished in red, buff and graphite. An example of "Swazi" pottery from Sekhukhuneland.
- (5) A small three-legged pot, in polychrome ware from Sekhukhuneland.
- (6) A spherical pot with a short flared neck, in a polychrome ware with an elaborate arcade motif. From the Lydenburg district.

Text Figure No. 5. Venda Pottery.

- (1) Bowl with pedestal base. In a reddish clay with graphite burnish on part of the interior. From Sintshumulo's village. Louis Trichardt. Durban Museum.
- (2) Small spherical pot with a flattened base. In a polychrome ware. From Messina. Durban Museum.
- (3) Pot with a short vertical neck, in a polychrome ware. From Mphefu's village. Louis Trichardt.
- (4) Cup with a short pedestal base. In a polychrome ware. From Mphefu's village, Louis Trichardt.
- (5) Gourd-shaped pot. As last.

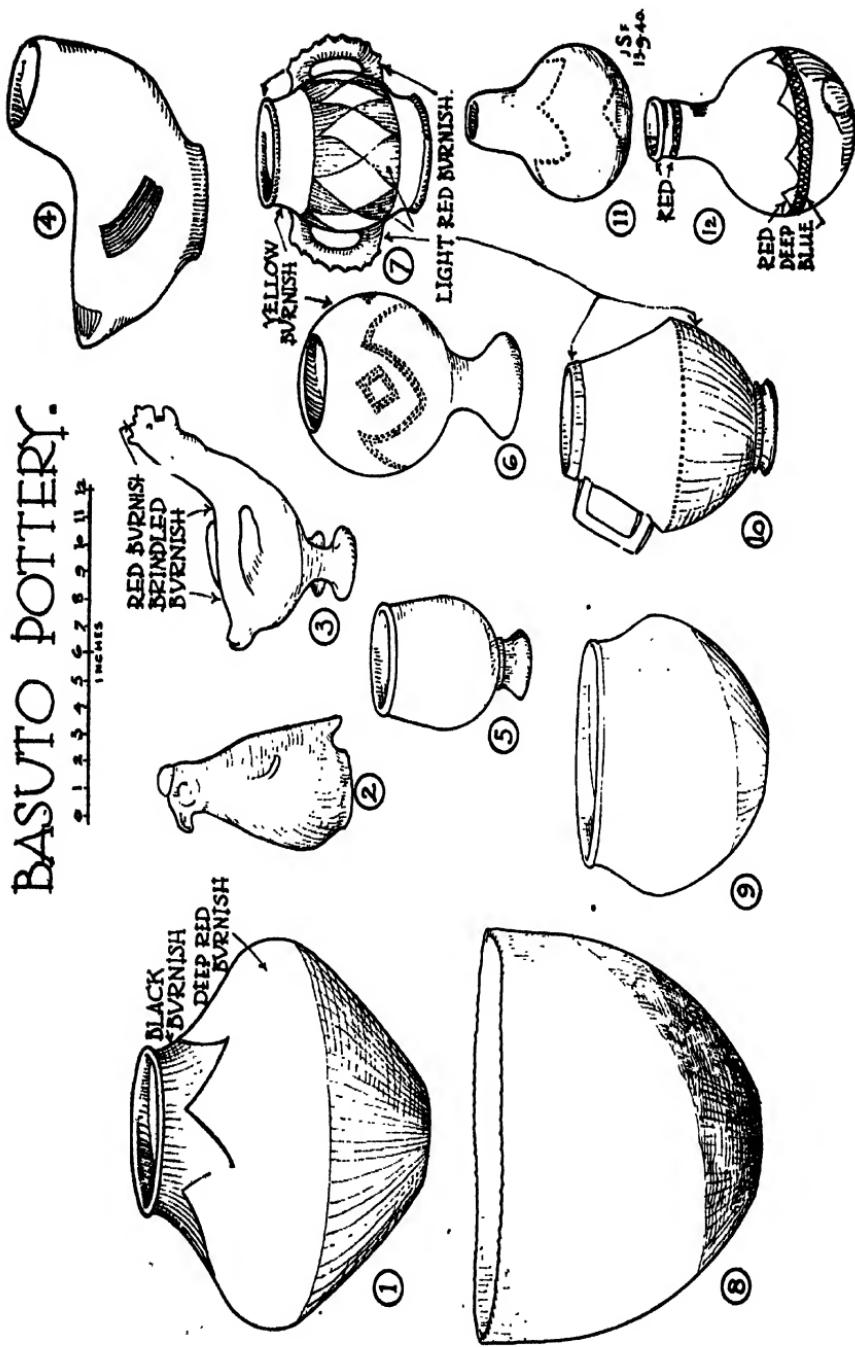
NGUNI POTTERY.

— 1 + 2 + 3 + 4 + 5 —



BASUTO POTTERY.

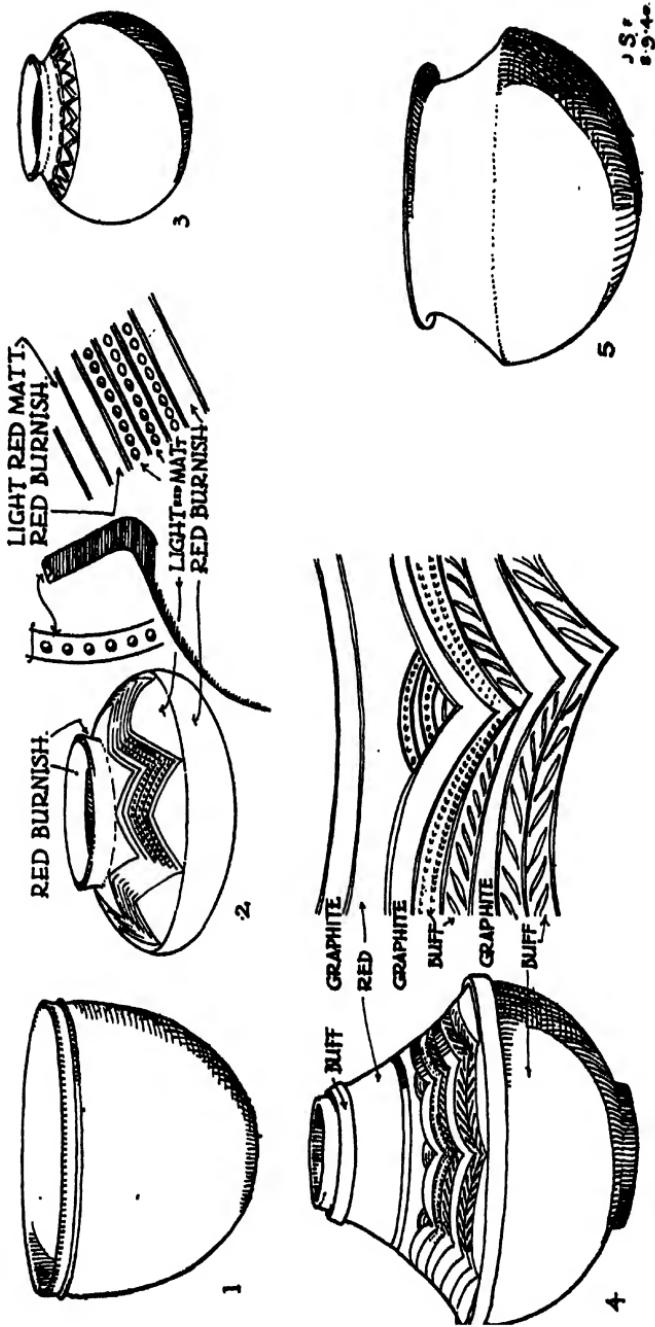
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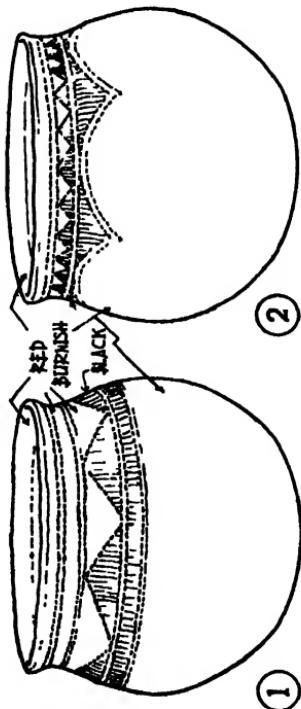
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SCALE for Nos. 1 & 4.

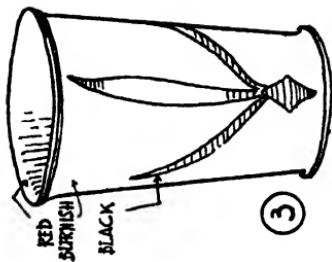


PEDI POTTERY.

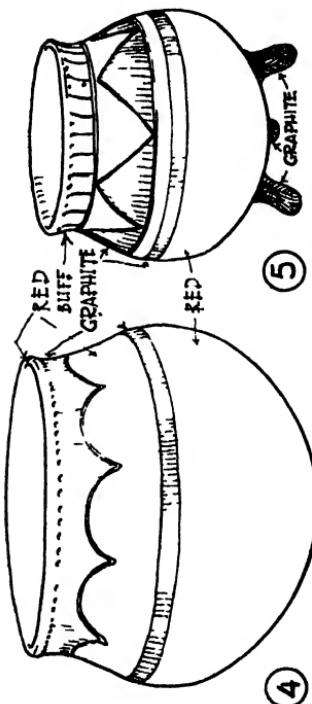
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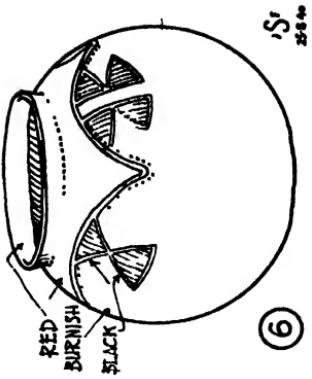
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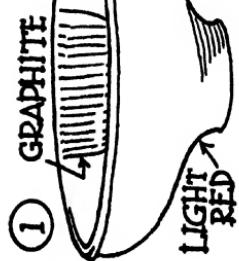
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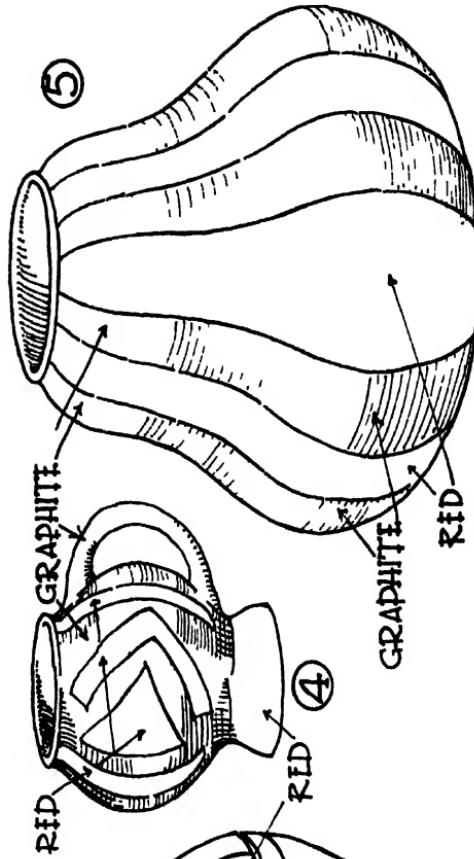
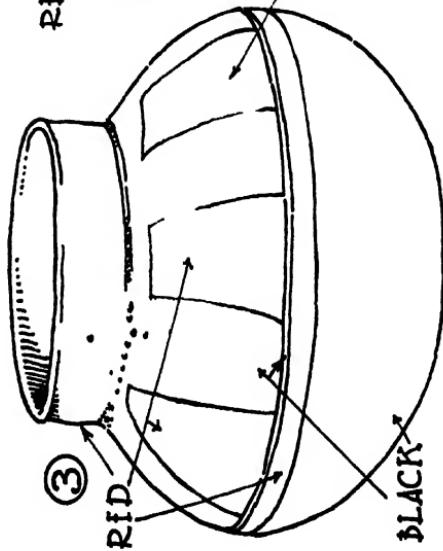
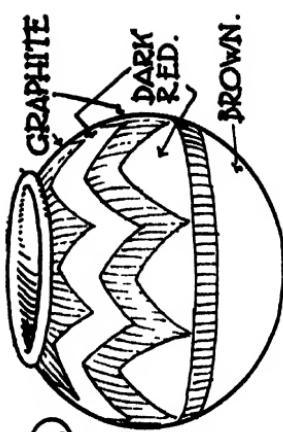


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VENDA
POTTERY.
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ON SOME REMARKABLE GRAVEL DEPOSITS ON THE KORNET SPRUIT, BASUTOLAND

BY

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Read 29th June, 1942.

During a short visit to Maseru, Basutoland, in June, 1941, I was informed by Mr. L. H. Collett, an Agricultural Officer living there, of a high level gravel deposit on the Little Caledon River. I visited the site and observed a number of implements on the exposed eroded surface of the gravel bed and also in the face of a large pit which was being worked in order to obtain gravel for road surfacing. Although many of the surface implements were of definite Levallois forms, many were heavily rolled and some very lightly; no definite fossil types of a Levallois form were obtained from the pit, so the lithic age of the bed was one of conjecture.

On a second visit to Basutoland in December, 1941, I excavated part of the bed; but apart from the recovery of one implement of Levallois form from a depth of 4 feet and a number of crude worked flakes, cores and small pebbles, nothing further was obtained.

This site is situated on the right bank of the Little Caledon near the Maseru-Morija road and about 300 yards down stream from the mill and bridge; the gravel bed is about 150 yards from the river and takes the form of a small mound at approximately 60-75 feet above the river bed; the gravels are composed of heavy grits, and pebbles of basalt, quartzite, agate and chalcedony.

The pit is about 8 feet deep and 100 feet in diameter.

The depth of the gravel bed is unknown, and apart from its high level has little interest in itself; but when it is viewed in the light of the evidence from the Kornet Spruit its position and nature become more interesting.

Later, in company with Mr. Collett, I visited Mohale's Hoek, where Mr. Tennant, the Agricultural Officer there, informed us of a somewhat similar exposure of river gravels on the Kornet Spruit, which were also being worked in order to obtain road material. As these Kornet gravels were to be seen on our return route to Maseru, I took the opportunity of examining them; I was so impressed with the remarkable topographical nature of the deposits, that I decided to return later in the week for a more detailed examination—it is on this later examination that this report has been based.

KORNET SPRUIT: This river is one of the seasonal tributaries of the Orange River, having its source in the Highlands of Basutoland. It follows a rather sinuous south-westerly course and enters the Orange River on the border of the Orange Free State. During my visit the spruit was almost dry, but during the rains it appears to have a flood level of about 15-20 feet, flowing between banks about 80 yards apart. (For a good topographical map of the region, see sheets 1 and 5 of the Union topographical series.)

KORNET SPRUIT SITE: On reference to Plate I, it will be seen that the site is relatively easy of access either from Mohales Hoek (5 miles) or from Mafeteng (25 miles); the road between these places passes through the site; the bridge over the stream is also a prominent land mark.

The distribution of the gravel beds is also clearly shown; when viewed from a short distance these beds have the appearance of a number of small mounds not unlike dolerite koppies of varying heights, flanking the right bank of the stream for a distance of 900 yards up from the bridge. On the left bank two other prominent koppies are seen, one resting on a sandstone escarpment, the other flanking the bend in the river; yet another koppie is seen at almost right angles to the river at the bridge, 350 yards away. These beds have been numbered on the diagram sketch, Plate I, according to their positions and will be described accordingly:

BED I: Height above river-bed 77 feet. This bed is the most extensive of the series and covers an area of about 900 yards long by 150 yards wide on the right bank of the river. When viewed from its highest point, i.e. 77 feet near Pit A, Plate I, the bed has the appearance of a number of undulating mounds not unlike a glacial terrain flanking a horizontal terrace-like spread of gravels of a similar nature; this terrace has a slight slope of about 5-10° towards the stream and is fairly level parallel to it. At first glance it appears to be a natural river terrace, as it could very well represent the course of a river which has gradually shifted its course from right to left until it came up against a flanking hillside (see Plate I) where the slipping process would be stopped, but there is evidence against this from the beds on the opposite side of the stream, which appear to indicate that the terrace is a false one due more to tectonic than water action. Over the whole of this gravel bed where it has been exposed, artifacts are lying about in profusion, more especially implements of a crude Levallois type. The amount of material which has no definite form is astonishing; the older cultures—Amalindan and Stellenbosch—which are also represented are heavily rolled. The terrace is overlain in parts with a deposit of black turf or cotton soil 1 to 3 feet deep.

Bed I has been opened and the gravels exposed in two pits which almost adjoin each other near the road and bridge (see Pits A, Plate I). These pits were excavated to obtain road material; they cover an area of about 600 square yards, 8 feet deep in the bank of one of the "mounds." The depth of the excavation has been governed by a convenient level for the road trucks, so the maximum depth of the deposit is uncertain at this point; a ravine cuts the "mound" about 50 yards away (see Plate I) and exposes the gravel at a depth of 30 feet, so the depth of the gravel at Pit A would appear to be from 30 to 40 feet. The pit exposure reveals a fairly heavy river gravel of sand, grits, and well-rounded pebbles from $\frac{1}{2}$ " to 8" x 4" x 4"; the major axes of the large pebbles are parallel to the stream in the section of the pit, which is also parallel to the stream. The bedding planes are fairly horizontal, but when viewed in the section at right angles to the stream, they appear to dip towards the present river bed; this is interesting and will be referred to later. When freshly exposed the gravels have a reddish appearance, but soon after exposure they change to a reddish grey; the pit gravels are loosely knit and not consolidated; they are composed of quartzite, banded quartzite, chalcedony, agate, jasper and pebbles derived from the Drakensberg lavas.

Tools were found in the Pit exposures from the surface to the Pit floor. No stratification of tool types was apparent; the old and later cultures (Amalindan, Stellenbosch and lower and upper Levallois) are inextricably mixed up in the exposures I made in the bank of Pit A; but if no direct evidence of stratification of stone cultures is apparent, it is quite clear that the closing stages of gravel deposition was marked by the laying down of upper Levallois tools. This would date the bed lithically as upper Levallois and for the want of a more precise geological term--upper Pleistocene.

These tools excavated from the bank of Pit A are figured in Plate III; others were observed *in situ* in the exposures made by the ravine; an interesting point then is the presence of these upper Levallois tools from the lowest to the highest levels of the gravels, again implying on archaeological grounds that the "Terrace" on gravel Bed I is a false one.

Another exposure of Bed I occurs just above the bridge; here the exposure is due to a ravine cutting through the later silts banking the river, and so exposing the gravels about 10 feet above the river bed; this is quite the lowest exposure determined, and would give a vertical height to gravel Bed I of 67 feet (see profile of Beds, Plate I).

BED IV: Opposite Pit A on the left bank of the river and 350 yards from it another mound-like gravel formation is seen. This elongated mound or koppie is considerably higher than the others (112 feet), and is also being excavated

for road material. Here the excavations were begun on the land side and not on the river side of the mound; the depth of the excavation again depended more on a convenient grade for trucks working the deposit than on excavating the bed fully. At present the mound is in the process of being truncated, and has exposed a face (about 12 feet deep) of coarse, cross-headed, heavy grits, with shallow layers of small pebbles, and larger pebbles sparsely interspersed throughout the bed. Although tools of a Levallois type are fairly common on the surface they are rare in the exposures; this would seem to suggest that this bed has been considerably eroded, the lighter material being carried away and the heavier stuff accumulating on the surface. Numbers of crude worked stones were found in the 12 feet exposure, but only one of a definite Levallois form (Fig. 9, Plate III). Two others have been illustrated but they were from the surface. Fig. 9 was recovered from a depth of 4 feet.

The Bed appears to be about 30 feet deep and to rest on a tilted sandstone platform the tilt being in the opposite direction to the flow of the river and about 80 feet above its bed.

The exact area of the gravel Bed is difficult to define, as the Bed appears to be covered by silt on the river side of the mound for about 300 yards from the river; this gives an area of 250 square yards to the exposed part of the mound.

BED III: About 500 yards upstream from Bed IV (Plate I) is another characteristic mound-like formation. Here the Bed rests on a sandstone escarpment, which forms the present river bank; this escarpment is 55 feet above the bed of the stream, and appears to dip slightly upstream; the height of the gravel bed is 77 feet, the gravel itself having a maximum depth of 25 feet. This Bed has not been exposed by excavation, but numbers of implements are lying on its eroded surface, Levallois forms again predominate; Bed III joins Bed II by a neck 50 feet above the river bed; the scarp appears to strike under the neck and re-appear on the opposite side (Plate I); if this is so, then the two beds are separated by a double escarpment, and the intervening trough is filled with silt.

BED II: This, also, is a fairly extensive bed of mound-like forms; it flanks the bend of the river for 300 yards, its height above the river bed being 65 feet; the depth of the gravel is uncertain but it appears to be considerably greater than in the other beds as it is flanked on three sides by a bank of later silts to a height of 30-36 feet from the river bed. Implements of a Levallois form are numerous on the surface of this bed, together with a great deal of crude material of indefinite type.

SILTS: From the top of this bed a good view of the upper reaches of the river is obtained; the river emerges from a valley of low-lying silts flanked by the escarpment into the area of high river gravels described here. In entering the high gravel area the river swings round Bed II in a "U" bend, takes a right-angled turn below the escarpment of Bed III, and passes on flanking Bed I; the later silts flank the stream and form its banks at many points along its course through the gravels; the average height of the silts is approximately 35 feet.

Above the bridge on the right there is a short terrace of 15 feet, while on the left bank the silt appears to rise from 15 feet at the river bank to a much higher level away from the stream. On the left bank just above the bridge deep gullies have been cut in the silts, so disclosing pockets of the older gravel enveloped in them. These silts have a characteristic brown colour and appear to be very fertile; they are similar to those banking the Basutoland and Orange Free State rivers; they seem to have made a sudden appearance and to have continued to accumulate over a long period, but at the present time they appear to be in process of erosion; no implements have so far been recovered from them.

Gravel beds high above the beds of the existing river bed may be the normal residue of a river's power of erosion; when, however, a river is flowing over relatively soft sediments like the Stormberg beds, a depth of 112 feet may very well have been excavated from the time of the Levallois to the present time.

There are moreover other factors in this depth of 112 feet which appear to me to be at variance with normal river dissection:—

- i. The actual depth cut by the river since its apparent dissection of the gravel bed.
- ii. The great disparity in the heights of the four gravel beds above the present river:—
Bed I. 10 feet rising to 77 feet.
Bed II. 65 feet.
Bed III. 55 feet rising to 77 feet.
Bed IV. 80 feet rising to 112 feet.
- iii. The difference in the platform levels of Beds III and IV.
- iv. The position of these four beds in relation to the present stream.
- v. The position of Bed III on a possible fault scarp.
- vi. Rifting as a possible cause for the position of the beds in relation to the stream.
- vii. The cause of the silt deposition.

I. If the depth of the river cutting is measured from the lowest level of gravel exposure, it is only 10-20 feet below the sub-strata. This means that from the time of the dissection of the gravel beds in upper Levallois time to the present, the river has only excavated a channel 20 feet deep and 80 yards wide; this leaves a channel 90 feet and 580 yards wide to be accounted for during the upper Levallois period, which would suggest (a) that a river of aggradation changed to one of dissection and (b) then changed again to one of aggradation, in the latter change silt and not gravel was deposited. Apparently the river underwent its final change, and (c) again became a river of dissection cutting through the silts.

If change (a) did take place, indications in the form of river terracing and heavy gravels superimposed by lighter ones should be in evidence in the lower levels of the channel; there should also be a progressive sequence of stone cultures from the earliest on the top terrace to the latest on the lower terrace.

At Pit A, Bed I, however, the earlier stone-age tools, i.e. Amalindan, Stellenbosch and lower and upper Levallois are all together to a depth of 5' 6" at least, and apparently not in stratigraphical sequence but in marked modification of form due to rolling and abrasion. What happened then to effect the base-level of a stream which had persisted for so long a period and then suddenly underwent a process of dissection? If river erosion was responsible, then the change would have been gradual and indications of its effect in evidence. The mechanical efficiency of the river appears to have been fairly constant throughout the aggradation period and for some reason to have come to an abrupt end, followed by an apparent dissection of its bed and the deposition of later silts.

Visser, Söhngen and van Riet Lowe (1937) in their report on the Vaal River have suggested that the climate during Fauresmith II was marked by a period of semi-aridity finally becoming arid, and then followed by a wet phase and by the Middle Stone Age. If this were so, the Kornet was near enough to be similarly affected by the same climatic condition. If it is assumed that the upper Levallois on the Kornet was followed by an arid period and in turn by a wet one, then this wet period would be responsible for the dissection of the earlier stone age beds and for the deposition of the later silts. This would make the Middle Stone Age Period one of intense erosion, and the river during this Middle Stone Age period would have excavated a valley 112 feet deep and 580 yards wide, if the section from Pit A to Pit B is taken. Surely, if this were so, clear indications in the form of true terracing and heavy gravel deposits, together with Middle

Stone Age tools, should all be in evidence from the time of the invasion and dissection of the earlier beds on the Kornet and the Little Caledon!

II. *The disparity in the heights of Gravel Beds 1, 2, 3, 4.* The question at once arises as to the part taken by erosion and more especially by lateral erosion in determining the elevation and conformation of these beds. An anomaly at once presents itself, as Bed II (65 feet), which is the lowest of the series is not subject to lateral erosion. Bed I (74 feet) has been subject to the drainage wash from a flanking hillside, but this is now controlled by a natural drainage system. The peculiar elongated mound-like appearance may be due to the effects of lateral erosion, but there is a possibility that if warping has taken place, it is due to this cause. The apparent dip of the gravel strata in Pit A towards the river bed also suggests that movement has taken place after the deposition of the gravels. Beds III and IV are both situated on hill-spurs and are not now subject to wash from this hill-side; it would thus appear that although these beds have been subject to a long period of weathering, erosion has not been a dominant factor in determining the present relative heights or form of the beds.

III. There appears to be a difference of 28 feet in the levels of the platforms of Beds III and IV, the downstream platform being the higher; when the difference in gravel heights is compared the difference is greater still—55 feet.

The height of the platform which supports Bed I at Pit A appears to be about 40 feet; if the lowest height of the bed is measured at the exposure in the river bank it is only 10 feet, and the height of the platform supporting Bed IV at Pit B is about 80 feet. The height of the base level at Bed II is indeterminate, as the joint between bedrock and river bed is not exposed, but from the conformation of the bed, the gravel appears to be at least 30 feet deep—this would give a base level of 34 feet. The differences in platform levels are most marked and are not normal either across the stream or parallel to it. The difference in the form of the gravels at Pit A—"Potato"—and at Pit B—"Heavy Grits and Shingle" needs some explanation. If the gravel bed at Pit A represent the former thalweg of the stream, and the bed at Pit B the former right bank, then the absence of a corresponding left bank is difficult to account for by normal erosion.

IV. If the escarpment on which Bed III rests is a fault scarp and upthrow, then Bed I is a downthrow, which was accompanied by slight rifting in an easterly direction. If this is so, it provides an alternative explanation of the phenomena.

It would also explain the anomalous difference in base levels between it and Bed IV on the same bank, and the difference in the base level of the opposite bank.

V. The position of the four beds in relation to one another, and the apparent depressed valley of entrance and exit to and from the gravel beds are at variance with normal topographical expectations due to river dissection, even when the notorious vagaries of a river are kept in mind. The position of Bed I to Bed II is quite normal, if the stream has bisected them—the position of Bed III to these two beds may also be normal and due to the same cause; the position of Bed IV cannot be reconciled; it is, however, virtually an outlier, but definitely related to the other three beds. Its extraordinary height and distance from Bed I and its topographical position could be in keeping with a rift of the gravel bed and then the whole system of beds could be reconstructed and brought into alignment.

The right bank (Beds I and II) would be brought up to the left bank, Bed III would then fill the gap between Beds I and II which is now occupied by the river. The escarpment on which Bed III rests appears to cut through the neck separating Beds II and III, where it again exposes itself upstream between Bed III and the bridge. It is hidden by silts and it probably strikes quite close to Bed IV; if this is so and Bed I at Pit A is brought up to it, this would narrow the gap between Pits A and B considerably.

Another factor is the marked difference on the right bank where the sandstone is about 20 feet above the river bed, while according to site test carried out by the engineers, the sandstone foundation is 25 feet below the bed on the left bank.

VI. The deposition of later silts:—

The problem of the silts is an important one, and needs close investigation. The change in the Kornet from gravel to silt transportation appears to have been sudden and has not the appearance of a climatic fluctuation; the line of demarcation between the gravels and silts is too sharp to suggest a gradual change from gravel to silt and suggests an alternative explanation to the generally accepted one of repeated flood-plaining and subsequent thickening. If the weight of evidence brought forward in this paper is substantially correct, then the deposition of the silts may be closely connected with the presumed Kornet warping. If this movement was wavelike and mainly horizontal in its effects, then the river and tributaries would be profoundly affected by areas of depression and uplift. The depressed areas and fault troughs would accumulate silt until the river had built up a new base level; if, owing to readjustment, a slight elevation subsequently took place, this, in turn, would

lead to the cutting through of the silt beds—a process that may still be in operation.

POSSIBLE CORRELATION WITH COAST SITES.

If the high level gravel bed on the Little Caledon is also due to an uplift then the axis between it and the Kornet beds would strike north-south, and if the axis continued to the south, it would cut the Orange River in the neighbourhood of Quthing, where, if there had been a movement, evidence should not be wanting. If the axis was continued further, it would ultimately strike the East London Area—an area whence the writer has previously recorded evidence of upper Levallois tools in strata, which suggests that uplift and depression were joint factors in moving the strata to their present position relative to sea-level: Macfarlane (1936, 1937).

A suspected raised beach on the Durban Coast has been recorded by Brien (1935). For other Raised Beach deposits on the South African Coast, see Krige (1927) and Goodwin and Malan (1935).

The adovation of crustal movement as a factor in South African Archaeology is not a new one—du Toit has long been of the opinion that man was present in South Africa during the closing stages of the prolonged general upheaval and warping of South Africa and that "minor fluctuations, both of uplift and climate, extend down to the present day." (du Toit, 1933).

CONCLUSION.

1. A crustal movement is presumed to have taken place in Basutoland during the Upper Levallois (Upper Pleistocene). This is indicated by faulting on the Kornet Spruit.

2. The gravels described in this paper are possibly related to the old land surface gravels, e.g. "High Level," "Potato," and "Red" in the Vaal area; they have been described as "Old Gravels"—Visser, Söhnge and van Riet Lowe (1937), and are presumed to be sterile of artifacts and therefore to be of Tertiary Age—Lowe (1937). On the Kornet and Little Caledon, they are certainly Upper Pleistocene.

3. During the period of gravel aggradation on the Kornet, fluviatile efficiency appears to have been fairly constant; no climatic variations are in evidence in the exposures examined.

4. The deposition of later silts is probably due to a changed topography and drainage system brought about by a crustal warping.

It is possible that the Levallois does not extend to a greater depth than 5' 6" at Pit A that a cultural sequence of earlier tool types may be in evidence beyond that depth. This could only be proved by an excavation of the site, a

colossal and expensive task for a single investigator,—an excavation of Bed II may have very valuable results.

It is difficult, at this stage, to gauge the relationship of later types in the Kornet Levallois to (a) the Fauresmith and Blind River Levallois and (b) the Basutoland Middle Stone Age; it appears to approach more nearly to the two former than to the remarkably fresh-looking M.S.A. tools which appear to be widely diffused over lower Basutoland with a somewhat similar horizon to that existing in the Union. It is of interest to note that there is an M.S.A. site on the plateau of the famous Thaba Bosigo.

The writer is inclined to the view that there has been a hiatus extending over a considerable period in the practice of the two similar techniques in Basutoland, and it is possible that this may be due to other than climatic causes.

The writer is greatly indebted to Mr. R. Tennant of Mohales Hoek, not only for his hospitality, but also for his valuable services in taking the necessary photographs of, and levels on, the Kornet.

A great debt is also owed to Mr. Collett of Maseru, who made my visit to Basutoland possible. Mr. Collett has long held the view that earth movements have been a factor in some Basutoland soil erosion problems.

REFERENCES.

- BRIEN, P. G.: Late Pleistocene and Recent Strata at Durban North. This Journal. **xxxii**: 642-649 (1935).
- DU TOIT, A. I.: Crustal movement as a Factor in the Geographical Evolution of South Africa. *S.A. Geogr. Journ.* **xvi**. (1933).
- GOODWIN, A. J. H. AND MALAN, B. D.: Archaeology of the Cape St. Blaize Cave and Raised Beach. *Ann. S. Afr. Mus.* **xxiv**. (1935).
- KRIGE, A. V.: An examination of the Tertiary and Quaternary Changes of Sea Level in South Africa with special stress on the Evidence in favour of a Recent World-wide Sinking of Sea-Level. *Ann. Univ. Stellenbosch.* **V.**, a.1. (1927).
- LAIDLWER, P. W.: The Archaeological and Geological Sequence in the Transkei and Ciskei. This Journal. **xxxI**: 535-546 (1934).
- MACFARLANE, D. R.: Evidence of a Pre-Chelleean Culture from the East London Clays. This Journal. **xxxII**: 537-550 (1935).
- MACFARLANE, D. R.: On the East London Levallois. This Journal. **xxxIII**: 893-903 (1936).
- SÖHNIGE, P. G., VISSER, D. J. L., AND LOWE, C. VAN RIET: Geology and Archaeology of the Vaal River Basin, Memoir No. 35, Geol. Survey of the Union of S. Afr. (1937).
- VAN HOEPEN, E. O. N.: Some Aspects in South African Archaeology, Arg. Nav. Nas. Mus. Bloemfontein 1: No. 9 (1939) (English reprint from this Journal. **xxxv**: 92-126 (1939).)

SCALE: IN.

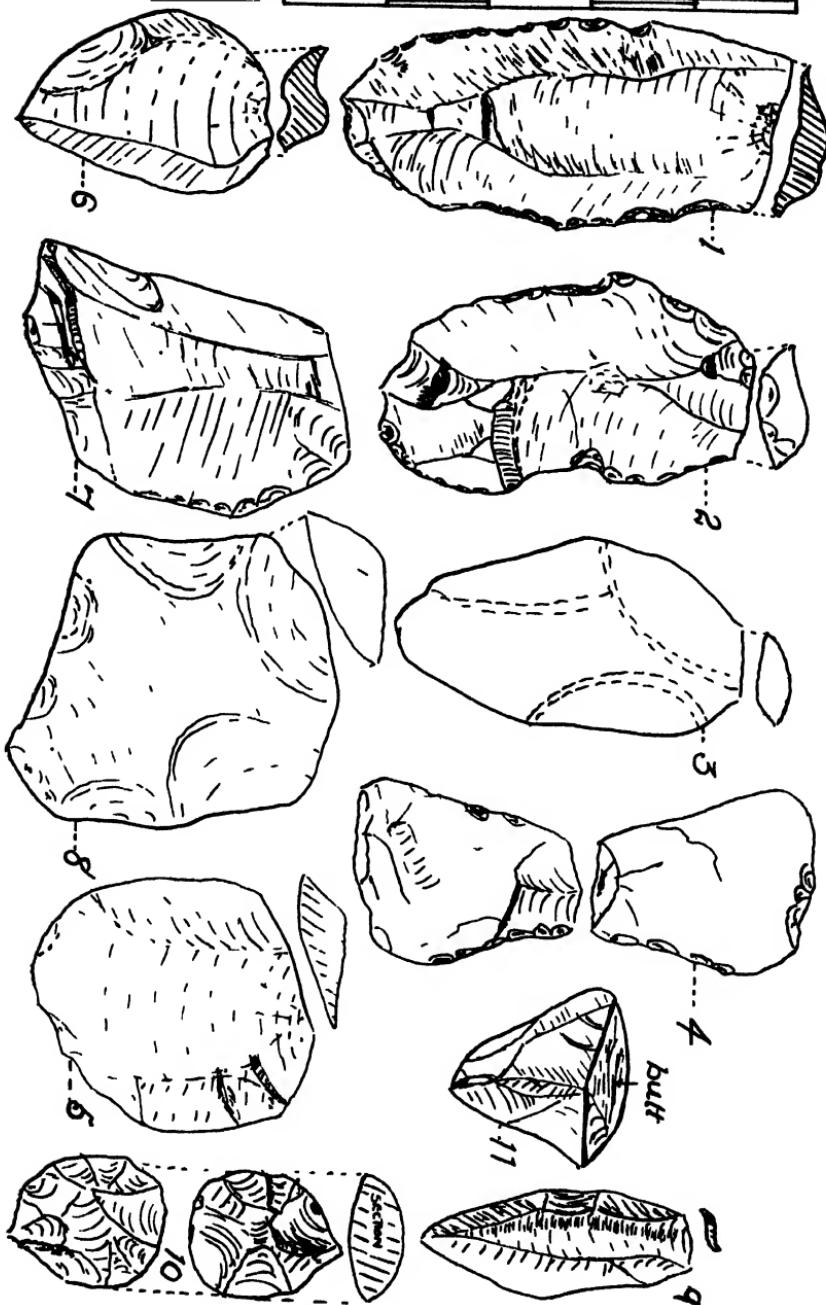


PLATE 3. Levallois tools from the Kornet Spruit.
Upper Levallois: Figs. 1, 2, 4, 5, 6 from Pit A, bed 1.
Lower Levallois: Figs. 3, 7, 8 from Pit A, bed 1.
Upper Levallois: Figs. 9, 10, 11 from Pit B, bed IV

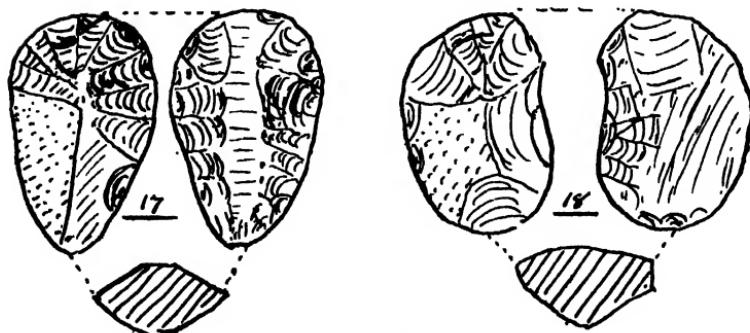
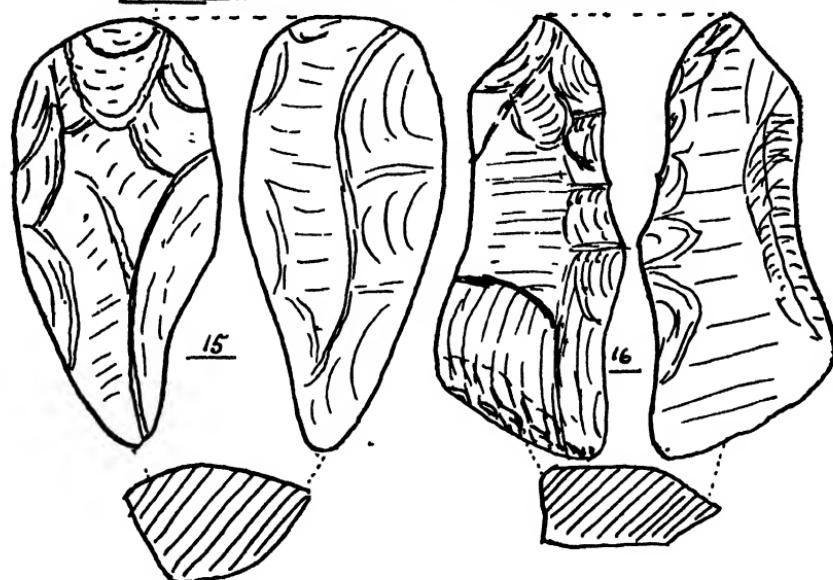
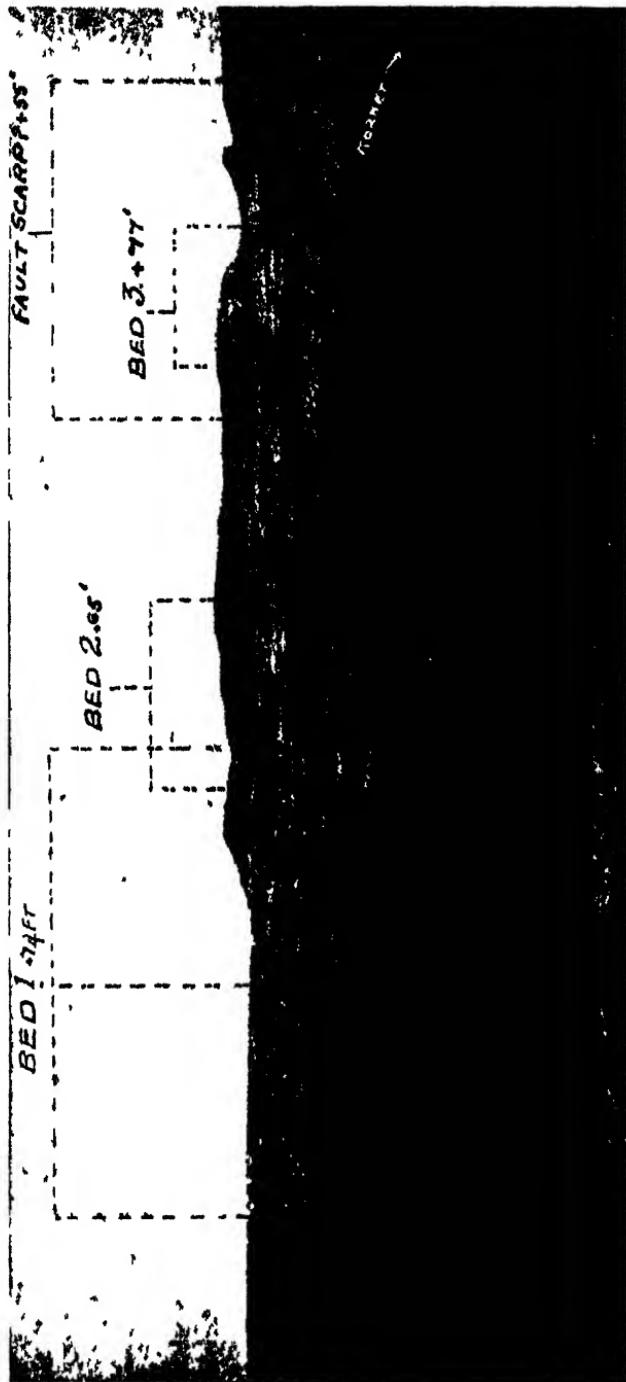


PLATE 4. Tools from Kornet Spruit.
Amalindan Pebble type: Figs. 12, 13, 14 from Pit 1, bed 1.
Stellenbosch: handaxe, Fig. 15, from Pit 1, bed 1.
Stellenbosch: nosed cleaver, Fig. 16, from Pit 1, bed 1.
Levallois: handaxes, Figs. 17, 18, from Pit 1, bed 1.



View across stream from near Bed 4, showing the koppie like formation of Gravel Bed 1.



View up stream from near Pit A showing position of gravel beds. Arrows indicate highest points of beds. Levels taken from present river bed.

SOUTH AFRICAN JOURNAL OF SCIENCE, Vol. XXXIX, pp. 297-306.
January, 1943.

NOVEL TYPES OF ARTEFACTS FROM A MIXED
WILTON AND MIDDLE STONE AGE SITE AT
KOWIE WEST

BY

JOHN HARCUS.

With 3 plates and 1 text-figure. Read 29th June, 1942.

During visits from 1931 to 1933 and subsequent trips up to 1935, crumbling middens, some four miles west of Port Alfred and the areas between them provided a wealth of artefacts. Much of the collection is wind polished and weathered, but still obviously of human origin, and apparently contains a mixture of Wilton and Middle Stone Age cultures. The specimens were collected from one-day wind-pits (here to-day and gone to-morrow) in the sand dunes, and from gulleys, trap rock ledges and surviving kitchen-midden mounds. Mostly microlithic, the average specimen in two soap-boxes full was about almond size, the materials being quartzite, "lydianite" and some silcrete. The specimens immediately aroused the interest of Professor Raymond Dart, who most kindly provided facilities at the Medical School, Johannesburg, where over some three months, I was able to sort the mass of material.

Thus, by 1933, the typical Wilton groups of type tools were sorted out, and even with subsequent weeding out over nearly eight years, still amount to some 700 specimens. The list therefore, is long, but will tend to show that the recognised types are representative of the Wilton and Middle Stone Age.

List of Wilton and Middle Stone Age Artefacts from Kowie West.

		Size.	Number.	Material.
M.S.A.	Points (worked)	1"-3"	32	Quartzite & Silcrete
"	(not worked)	"	70	"
"	(worked)	1"-2"	10	Lydianite "
"	(not worked)	"	40	"
Biface	(Still Bay type)	2"-3½"	3	Quartzite
M.S.A.	Backed Blades	2"-3"	10	" & Silcrete
Backed Blades		1"-1½"	20	14 Quartzite & Silcrete, 6 Lydianite
(From colourful materials)				
Thumbnail scrapers		Av. ½"	54	"jade," etc.
Larger scrapers		1"-3"	40	Silcrete & Quartzite

Backed Blades, "Trapezium"	forms worked diagonally, both ends	$\frac{1}{2}$ " flakes	21	Silcrete
Hollow scrapers or spokeshaves			6	Lydianite
Kasouga Flakes (worked) (Hewitt 1933)	1"— $1\frac{1}{2}$ " (9 worked one edge & 4 both edges)	2 $\frac{1}{2}$ "	11	Silcrete
Crescents.	@ 1"		13	Lydianite & Silcrete
Cores, from pebbles	@ 2"		10	Silcrete
Cores converted by fluted flaking, one end, chisels?			8	Lydianite, Quartzite and Silcrete
			6	Lydianite & Silcrete

In addition there is a mixed batch of worked specimens, difficult to classify, and only to be identified by further finds, or comparison with other collections of these periods.

During the original sorting, a number of groups of specimens, suggesting novel types, emerged and were commented on by Prof. Dart, Dr. A. Galloway and Dr. L. H. Wells, who were interested visitors and helpers at times.

In introducing these novel types, it is necessary to point out that, to a craftsman, *recognised* types do not cover satisfactorily the method of *producing* some of the more elaborate artefacts, contemporary beads, shaped objects in stone, etc., nor do they account for the *purpose* of several peculiar types of unmistakable artefacts. It is competent for research workers to discuss the "why" and "what for" of groups of purposely-made artefacts and to engender speculation, which may lead other collectors to re-examine their artefacts in the light of these novel types claiming an individuality and a recognised purpose.

Sayce (1933) says: "The function of an implement is one of its essential characteristics. The function and structure are mutually dependent (p. 97). "Until we know what an implement is used for, it remains an enigma, and it is difficult to provide it even with a satisfactory name" . . .

"The question of function is important in discussions concerning *independent inventions* and diffusion" (p. 98). "The question of function has been dealt with at some length, because its importance is sometimes overlooked" (p. 100). "It is only information of this kind that can make our studies alive and practical, and so supplement the valuable teaching that can be obtained from our Ethnographical collections." "Of equal importance, too, is the bearing of *function or use* on the development of an implement and its structure." (Italics are mine.)

I am a life-long craftsman, a carver in wood and stone

and a Transvaal Education Department Instructor on Crafts for 23 years. My knowledge of tools and how they work, leads me to regard a novel type of implement from several unorthodox viewpoints. What was its purpose? What need created the urge to fashion this peculiar artefact? Given a type of contemporary ornament requiring a peculiar tool to produce it, and no recognised tool-type which could perform the process, was there in my unclassified types, a "tool" which could do the work. Finding a type which could perform the process, there arises the final question "Could this result be achieved by any previously recognised artefact, or by any other known means?" The list of specimens from this area bespeaks a mixed Middle Stone Age and Wilton site. "Backed Blades" are a recognised type in most Middle Stone Age assemblages: it has fallen to this mass of material from the Kowie, unworked and worked, to provide from its debris new light on the *evolution* of the backed blade. To quote Sayce again: "It is sometimes possible to *arrange specimens in a sequence* which probably illustrates the general course of development, starting from a natural object, scarcely, if at all, modified and leading to a comparatively complicated tool or weapon."

In a paper now in press (Malan 1942; Bureau of Archaeology) under the heading "Backed Blades" we read: "It is of interest here to note that a collection of Middle Stone Age material gathered by Mr. John Harcus in the Kowie Sand dunes and now housed in the Bureau of Archaeology, contains a complete series demonstrating this 'pebble' backed blade technique. The series contains plain 'quarter orange' flakes, specimens with trimmed and utilised chords, specimens on which the backing provided by the cortex has been improved by flaking across the thickness of the implement, in the manner of normal backed blades; and others, indistinguishable from normal backed blades, in which the whole cortex has been removed by such secondary trimming."

To prevent confusion, the "Novel Types" which follow have been sorted into alphabetic-designated type-groups: these Groups have been subdivided into progressive "sets," with numerals.

TYPE A: PEBBLE BACKED BLADES:

Set A: Untrimmed orange divisions, or sectors of ovoids, from quartzite pebbles (18 in set). With one exception, these show signs of a blunted end, or prepared "striking platform" and a *bulb of percussion* at the blunted end. 3 of this set "A" 1, 7, 15, are illustrated (in Plate 1) showing range of size.

Set B: Preliminary experiments in trimming, 6 examples, (4 showing prepared butt) arranged in order of progressive trimming. (Plate 1, "b" 3), two large flakes removed, "b" 6, all trimmed but central flake, serve to illustrate this stage.

Set C: Seven examples in quartzite. Back flaking complete, chords showing signs of use. No. "c" 4 and illustrated (Plate 1). These are typical orange slices. (There are also 3 in lydianite, showing progressive stages of development.) Eight of these ten show the prepared platform, and a "bulb" of percussion. There are, in all, over 50 of these "orange slices" or "lunes."

How was the ovoid pebble split into these orange division slices? From the frequency with which specimens with "prepared ends" occur, one surmises firstly, that the ovoid pebble was "pecked" on one end. It was then seated in a hollow in the black shale rock out of which a pebble had weathered, and by a "directed" blow, was split into fragments, some of which were the desired sectors, or "lunes." Actual experiment has confirmed the possibility of obtaining these sectors in the manner suggested. Ovoid pebbles of coarse quartzite formation from the Rosettenville conglomerates, were pecked on one end to form a striking platform. The smooth (untouched) end was then rested in a natural hollow in a fixed rock. A blow then struck with a large ovoid hammer-stone on the pecked striking platform. shattered the pebble in such a way that sectors were obtained. Seven pebbles yielded 3 sectors (Plate 1, fig. J.H. 1, 2, 3) illustrates these.

2nd Novell Type. "B."

Tattooing Points: A Set which attracted attention at the Medical School in 1933 was labelled "Tattooing Points?" in 1936 and exhibited at the Scientific Technical Conference at the Witwatersrand University, where it aroused considerable interest. Dr. Heese and other visitors said they would look out for my "short points" in future.

Dr. F. H. H. Roberts (1936) writing on "Gravers and Chisel Gravers" referred to "short points which might have been tattooing points" which he had found in Colorado in 1934, 1935 and 1936. He suggests that "another possible function for the graver type of point is its use in tattooing. The very sharp tip would readily puncture the skin for the application of pigment." Further Dr. Roberts proceeds: "Most . . . consist of chance flakes, modified only by the presence of a short needle-like point on one side or end. The small sharp points were not fortuitous: they were definitely chipped."

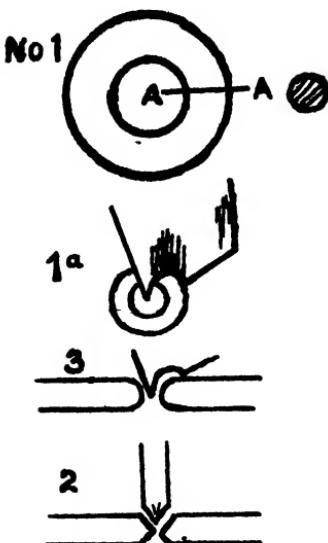
My quartzite and indurated shale specimens (Plate 2.

Nos. 1 to 11) from Port Alfred are *equally well described* in Dr. Roberts' words, notably "chance flakes"; and that "the tips were not fortuitous, they were definitely chipped." An accurate description of these artefacts would be "Flakes, having a blunt thumb-like end, reduced away at sides to leave a central 'tip,' or sharp piercing point, which would go only skin-deep."

The large quartzite specimen (Plate 2, No. 1) was found in 1935 by my youngest son in the Bedfordview area, east of Kensington, Johannesburg, and answers in each particular to the description above. A hard white vein in the yellowish quartzite has been "assisted" by skilful chipping, to produce an ideal gauged point. The Kowie specimens were sorted, named tattooing points, and described by me in 1933: Dr. Roberts' finds were made in Colorado in 1934-5 and 1936. In considering these gauged points one must appreciate the definite special intention indicated in the *laborious production by deliberate chipping* of a *short sharp point* on a blunt end. If it was only to pierce *dead* skins or hides, any borer or sharp splinter would suffice, as going too deep would not matter. It is difficult to imagine any other function than deftly puncturing the human skin, which would justify the elaborate work involved in producing these gauged points, laboriously fashioned to go only skin-deep. Photoplate 9 in Dr. Roberts' brochure compares convincingly with the Kowie type illustrated in Plate 2, 1 to 11).

The possibility of artefacts fashioned for tattooing is mentioned as hereunder by de Morgan (1924) with reference to some long sharp spike-like points found at le Madelaine: "There are even some amongst these implements so fine that it has been supposed they were designed to pierce the eyes of bone needles, or to prick the skin for tattooing." (These had "no limit": Dr. Roberts' and the Kowie specimens are *gauged*.)

TYPE C: A bead with a circular cross section cannot be produced by means of an awl. Such beads have been found at the Kowie site and are also to be seen in other collections in the possession of the Bureau of Archaeology. It requires a special tool to produce the internal rounding: the only tool which could fashion this must have a pivot-point and a cutting notch, as illustrated in these sketches, and in Nos. 12, 13, 14, 15 and 16, Plate 2. Of these, 14 and 15, in Silcrete, could do the job. They are again fortuitous flakes, upon which notches have been produced, or assisted by chipping, to acquire the necessary point and notch. The lydianite flakes may also have been similar tools, but the effect of sand-blasting and weathering has reduced their value as specimens. A special borer must have been used: there is the bead—here is the tool! An ordinary awl would produce a cone-shaped hole.



If a tool like this is not admitted, this internal rounding cannot be accounted for.

TYPE D: Stone Bodkins: These three artefacts in various materials again show the fortuitous flake, and the application of craftsmanship to achieve a required tool. They were all "freaks," a flake, a "point" and a pebble sector, each with a small knob on the thin end. The craftsman saw their possibilities and by careful chipping he produced a notch behind that knob, and even undercut it a little, till he had produced a "hook." The tool was possibly produced to undo loops, in stitching with sinews, and to tighten a thong round a shaft or handle (Plate 1 D, 1, 2, 3).

TYPE E: Oblique-notch thong-dressers: Again fortuitous fragments were adapted to suit a definite purpose. All four notches are *smooth and glossy* in the groove, while deeply pitted and weathered on all other surfaces. A flake with a natural notch worn to its oblique shape by its swinging use in the hand, in producing flexibility in gut and sinew. The cobbler's wax gets much the same groove as he swings it up and down the thread. Tools which occur in a habitat where subjection to the age-long sand blasting of the elements is inevitable, if found in duplicate or sets possessing similar characteristics, must be given recognition. (Plate 3, E 1, 2, 3, 4.)

TYPE F: Spoons: Perhaps originally picked up to use as a lever to prise open the tight shell valves of the "mussel" which formed an important part of the food of the Strandlopers, these first "spalls" off pebbles seem to have developed into a useful spoon-like tool.

Here is another example of what Sayce (already quoted) draws attention to, viz. the possibility of "arranging specimens in a sequence . . . starting from a natural object—leading to a comparatively complicated tool." I did not make these artefacts: I found and arranged them in sequence.

Of the first set of 4, 3 show bulbs of percussion. No. 3 is illustrated to show this stage (Plate 3, fig. F 3). The next set of seven show progressive flaking to achieve shape and lightness (No. 10 illustrated (Plate 3, fig. F 10). On being picked up, 10 of these eleven settle *naturally* into one's fingers at the bulb end.

Set No. 3: 4 specimens, showing more workmanship are illustrated, and the wedge tends to become an ideal scoop to dislodge the molluse from the hollow shell. (Plate 3, figs. 12, 13, 14 and 15). The bulb is still at the natural handle end. Here are 15 spalls, progressively arranged, from the crude spall to the delicate final specimen, No. 15, with its stepped flake off the upper surface: and in every case, the bulb-end is the natural "handle" end!

TYPE G: Nostril spoons: Set No. 1 consists of 6 smaller spalls arranged in order of amount of working. (Plate 3, figs. G, 1 and 6.) These resemble the bone and ivory nostril spoons used to-day amongst the Zulu, Pondo and Sutho. Again, the bulb comes into the fingers naturally. Seven Type G, Set No. 2, lighter and with finer working. (Plate 3, G 10, 11, 12.) No. 12 resembles in a crude way the light and delicate bone nostril spoons of the Pondo tribes. To the last one, *the bulb is at the natural "handle" end.*

To sum up. Probably in all collections in Southern Africa there are single examples of *peculiar* artefacts, arousing unsatisfied speculation in the mind of the owner, as they catch his eye.

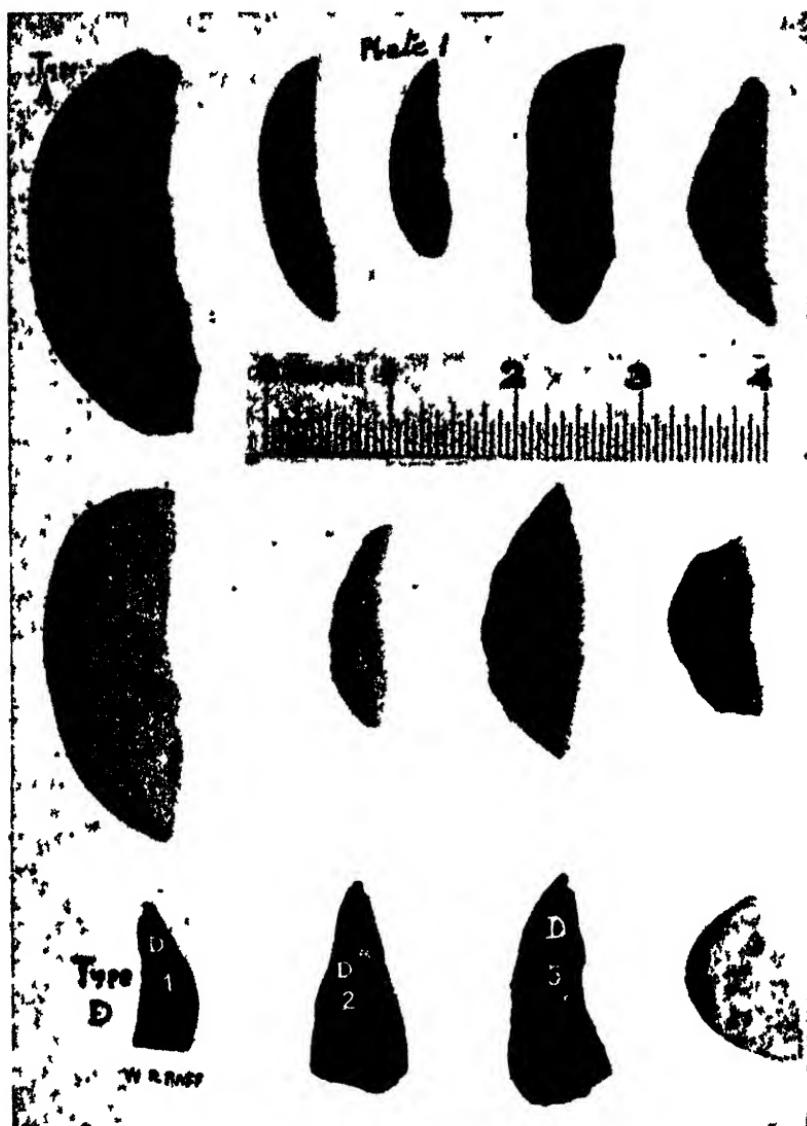
Considered from the "function" point of view, stressed by Sayce, these odd artefacts are significant items "independent inventions" and "enigmas," and will so remain until we give them publicity. It is an obstruction to progress *not* to do so; as "it is only information of this kind" (and the free exchange of it) "that can make our studies alive and practical, and so supplement the valuable teaching that can be obtained from our Ethnographical collections."

My thanks are due to Professor Dart and his staff of 1933 and later, and to Professor van Riet Lowe and Mr. Malan of the Bureau of Archaeology for their advice and kind assistance at all times.

I also wish specially to thank Mr. Paff for his assistance with the photographs.

REFERENCES.

- HEWITT, J. On the Implements known as Kasouga Flakes This Journal XXX. 552 (1933)
- MORGAN, DE "Prehistoric Men," p. 63 (1924).
- ROBERTS, F. H. H.: Additional Information on Folsom Complex Smithsonian Institute Miscellaneous Collection XCV No. 10 (1936).
- SAYON, R. V.: Primitive Arts and Crafts, Camb Univ Press, p 61-97, 98, 100 (1933).



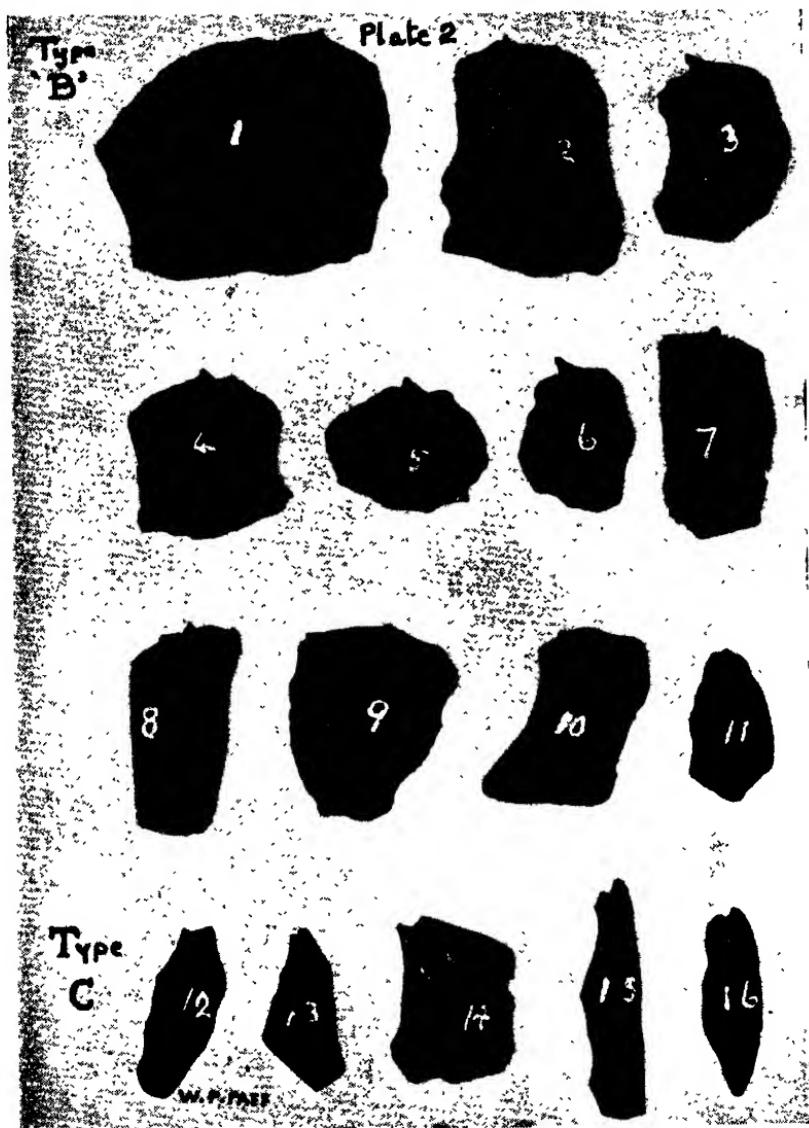


Plate III



W. P. PASS

SOUTH AFRICAN JOURNAL OF SCIENCE, Vol. XXXIX, pp. 307-310
January, 1943.

**WILLIAM THRELFALL AND HIS HOTENTOT
 MURDERER**

BY

PERCIVAL R. KIRBY.

Read 29th June, 1942.

I.

In the year 1825 a young Wesleyan missionary named William Threlfall, twenty-six years of age, was residing at Lily Fountain in Namaqualand. He had been compelled by sickness to leave his own mission station at Delagoa Bay, and he had journeyed thither in order to recuperate.

Although he was far from well, his zeal for his work was so great that he begged the missionary Barnabas Shaw, who was in charge at Lily Fountain, to let him travel north to the Fish River in company with two converts named Jacob and Johannes Jager, to examine the possibilities of establishing a mission station there.

Shaw had planned to undertake this journey himself, and had even procured a pack-saddle and other necessaries for the purpose; but for various reasons he stood aside and allowed the younger man to go in his place. Towards the end of June the little party left for the north but none of its members returned alive.

Having left Lily Fountain, Threlfall and his companions journeyed to Warm Bath. The petty Hottentot chief of that place put every possible obstacle in the way of their proceeding to the Fish River. They had therefore the choice of either returning to Lily Fountain with their object unachieved, or of risking undoubted personal dangers and making for the north. They decided upon the second alternative, and left Warm Bath without a guide. But after only four days' travelling they lost an ox, and were compelled to return to replace it.

They departed from Warm Bath for the second time about the 9th or 10th of August. They took with them as guide a Bondelzwart Hottentot named Nauwquaap, "a dirty, repulsive-looking fellow, capable of any crime." Scarcely had the party started when it was joined by several other men on the advice of the guide, but against the wishes of Threlfall. One of these men had a gun.

On the first or second night after their departure from Warm Bath, Mr. Threlfall, Jacob and Johannes were taken

to a Bushman kraal, and left there alone for the night. Just after midnight Threlfall was aroused by the report of a gun. The Bushmen, led by the guide Nauwghaap, had entered the kraal with the others, all being armed. Jacob and Johannes were murdered almost immediately, but Threlfall had time to offer up a prayer before a stone flung by the treacherous guide did its deadly work.

Several months elapsed before the news reached Shaw at Lily Fountain, and when he had confirmed it he informed the Colonial authorities. But it was not until 1827 that the murderers were apprehended. They were two Bondelzwart Hottentots, one being the guide Nauwghaap, and the other a far weaker character named Conghaap.

It was the latter who related all the details of the crime in Court, and who also told how he had informed his own chief of what had taken place. Nauwghaap was sentenced to death, and his companion was ordered to receive forty lashes with a sjambok. But the actual execution of Nauwghaap had to be undertaken by the Bondelzwart chief himself, the place of execution being Silverfontein, just over the border of the Colony.

On the evening of 24th August, Nauwghaap arrived at Silverfontein under escort. There the Landdrost of Clanwilliam and his secretary, the missionary Mr. Marquard, and two Field Cornets were awaiting him.

It is interesting to note that some of the Namaqua-sail that, had Nauwghaap not been in the hands of the Landdrost, they themselves would have killed him. This was probably due to the fact that Nauwghaap had stated that the Bondelzwart chief had instigated him to commit the crime.

On 2nd September, almost a week later, the son of the Bondelzwart chief arrived, as the chief himself was too old to travel so great a distance. The son was accompanied by a bodyguard of twenty-three men, nearly all of whom carried firearms.

On 3rd September the sentence was carried out. A grave was dug, Nauwghaap was placed beside it, and a firing party of six of his fellow-tribesmen was told off for the execution.

Thus the curtain fell on the tragic tale of the murder of William Threlfall.⁽¹⁾

II.

In April, 1830, Carl Friedrich Drège, a young German apothecary who had practised his profession in Cape Town for several years, but who had lately turned professional museum collector and, with his brother Johann Franz Drège, a botanist, had begun to tour South Africa in search of saleable specimens, set out upon his second journey to Namaqualand, and in October he arrived at Silverfontein.

In his diary, which has been preserved, he entered the following facts.⁽²⁾

" 27th October. I heard that Abraham Naugap Saumap received a 'Captain stick' from the Government, which gives the owner the hereditary right [of chieftainship].⁽³⁾ He also received guns, powder and lead. Everyone who wants to travel or trade across the Gariep River has to announce himself to him, and to obey his commands. He has the right to put to death those who act contrary to his orders

" On the advise of this Abraham, Platje Saumap Naugap, a relative of the Captain, killed the missionary Threlfold, of the London Mission [sic], who was living there. Platje was condemned by a Commission at Zilverfontein, and was shot by Abraham's people

" 31st October. I let the waggons drive on ahead, and dug out the head of Platje Saumap Naugap. Carrying this and a long-haired jackal skin (*Proteles Lalandii*), and driving the one-year-old calf, I took leave of our friendly hosts Van Zyl and Van der Westhuizen, and went after the waggon. The calf refused to go on, no matter what I did, so I threw head, skin, coat and a newly captured and well-secured snake on to the road, and returned in the night to Van Zyl's.

" On 1st November, Piet, Gideon and I drove the calf. As I was riding without a saddle I rode more slowly, and found all my property again."

Undoubtedly Carl Friedrich Drège preserved the head, and I expect that it eventually found its way to Europe along with the thousands of other objects collected by the Drège brothers and sold by them to scores of museums overseas.

This was not the first occasion on which Drège helped himself to human remains. In September, 1829, while on a journey to Algoa Bay, Drège was camped at Zuurplaats, in the Agter Sneeuwberg. In his diary we read:

" 11th. Stormy night at Piet van der Merwe's, Zuurplaats. There are many Briquas (Kaffirs) living here, and they are hired as herds.

" 12th. With the son, Andries van der Merwe, Veld Cornet Michel Nieuwkerk, Hendrik du Toit, Jan Richter and I held an examination of an old stranger, a Bushwoman, who had died two thousand paces away of hunger and cold. She had been found dead by the Briquas, and Van der Merwe had her buried on the spot. In the afternoon I searched for the place in vain. Jan showed it to me. In the night I dug out the maid and hid the body under some rocks.

" 13th. Very cold night; I found thick ice. All the buds on the peach and plum trees frozen. Stormy. I began

to prepare the maid, but a Briqua surprised me while I was standing before the body. He did not venture to come too near. I hid the flesh and the bones under the rocks, and at midnight I brought the skin to the waggon in a sack, going in a wide circle round the kraals of the Bríquas."

I expect that this skin also found its way to Europe in the course of time.

It may be possible, after the war, to trace these two specimens. The first of them would be of the greatest importance to physical anthropologists, since it is representative of a particular Hottentot tribe the precise provenance of which is well known.

REFERENCES.

1. *Missionary Notices* for 1826 and 1827, *passim*. See also Shaw, B., *Memorials of South Africa*, London, 1840, pp. 188-198, and Cheeseman, T., *The Story of William Threlfall*, London, 1910, pp. 64-152.
2. *Autograph Diary of Carl Friedrich Drège*, 1828-1845, unpublished, quoted from by kind permission of Mrs. Ida Rosenbrock-Drège.
3. SHAW, B., *Memorials of South Africa*, London, 1840, p. 201. (The staff of office was given to the chief in Cape Town by the Governor, Sir Lowry Cole, in August, 1830.)

THE UTILIZATION OF MEDICO-SOCIOLOGICAL DATA IN THE THERAPY OF HOMOSEXUALITY

BY

L. F. FREED.

Read 29th June, 1942.

PHILOSOPHY AND POST-WAR RECONSTRUCTION

BY

R. J. JORDAN.

Read 30th June, 1942.

SCIENCE AND POST-WAR RECONSTRUCTION

SYMPOSIUM, WEDNESDAY, 1ST JULY, IN PLENARY SESSION.

Chairman: The Hon. J. H. Hofmeyr, Minister of Finance and Education.

Conveners: Professor John Phillips, Mr. Jas. Gray, Dr. J. B. Robertson.

In accordance with the declared policy of the Government of South Africa, a serious effort will be made, on the conclusion of the war, to solve some of the vital economic and social problems of the nation.

These problems include: (1) The creation of productive occupations to supplement or succeed our two great industries, of which one is impermanent and the other has been injured—perhaps irreparably—by a century of neglect; (2) the rehabilitation of a section of the population enervated by malnutrition; (3) the development of the human resources of the nation physically and educationally, and the provision of economic security; and (4) the regulation of the industrial and social relations between Europeans and natives.

To these problems the war has added the prior duties of providing for the dependants of the dead and of rehabilitating those who have ventured life and limb and sacrificed their careers in defence of their country.

The Cabinet Council for Post-war Reconstruction, the Economic and Social Advisory and Planning Council, the Industrial Development Corporation of South Africa, and the Civil Re-employment Board now exist for the purpose of considering and advising on these problems, and the Council of the Association therefore arranged a Symposium, under the chairmanship of the Minister of Finance and Education, in which many aspects of these problems could be presented to members and visitors from a scientific point of view, and then be open to discussion.

SCIENCE AND POST-WAR RECONSTRUCTION

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(1) MESSAGE FROM THE PRIME MINISTER, THE
RT. HON. J. C. SMUTS, F.M.

Prime Minister's Office,
PRETORIA,
8th June, 1942.

Dear Phillips,

I am glad to hear that you are going on with the holding of your S.2.A.3. Symposium, and trust that it will prove a real contribution to the subject of Science and Post-war Reconstruction. I am also glad to hear that there is a possibility of Mr. Hofmeyr's attending, and I only regret that heavy calls on my time will prevent my also attending. However, his presence will give you the best sort of government support.

The future after this greatest of world wars is already beginning to form up before us, and it is wise to give our attention to the grave problems likely to arise. For real and lasting victory we have to win not only the war but also the peace, and while we give our full attention and energy to war problems we should not neglect the consideration of the peace problems following thereafter. A new world has to be built on the ruins of the old, and foresight and forethought and wise and prudent planning in advance may prove very helpful, and in this planning science should play an important part.

It is not so much a question of laying down definite programmes and policies. Indeed it would be presumptuous on our part to attempt to do so. We are only one in a grand company of 27 united nations who will yet be many more, and united action by all of us will be wanted as much for peace as for war. It could only be foolish and harmful for one or other of us to launch forth on declarations of policy which may disturb our united action in future and prove as much of a snare to us and an illusion to our enemies as the resounding 14 points of President Wilson did in the last war. Our general peace objectives have already been declared in the Atlantic Charter to which all the united nations have subscribed, and more specific declarations should be enunciated in the same united manner.

But this does not prevent careful consideration and discussion among ourselves of special problems which may arise without our definitely pronouncing on them, nor does it

absolve us from the duty of considering domestic questions, and policies which may concern South Africa more specially. The war will open up for us large opportunities to be followed up thereafter. It will also create domestic situations which will call for our highest constructive statesmanship. I need not here specify details, which are already receiving the careful attention of a special government committee, as well as of the Social and Economic Planning Council. But from the point of view of science a great contribution can be made to the discussions of Post-war reconstruction, and I hope such a contribution will be forthcoming from your Symposium. You have the great example of the similar discussions in the parent associations in Great Britain which are already exercising a potent influence on public opinion and public policy. I trust your effort will be no less successful so far as South Africa is concerned.

With all good wishes,

Yours sincerely,

(Sgd.) J. C. SMUTS.

Professor John Phillips,
University of the Witwatersrand,
Milner Park, Johannesburg.

(2) INTRODUCTORY REMARKS

BY

THE HON. J. H. HOFMEYR,

Three years ago I had the honour to preside at a Symposium arranged by the Association on the need for the investigation and conservation of the human resources of South Africa. To-day I have the honour to preside over this Symposium, which is to deal with the related subject of post-war reconstruction. There is, however, a difference between my own position then and now. Although you have invited me now, as you did then, primarily as an ex-president of the Association, I am now a member of the Government, and that was not the case then. I shall do my best to forget that fact to-day, but not before I have expressed the Government's appreciation of the action of the Association in holding this Symposium.

The Government appreciates the tremendous importance of the subject to be discussed. It appreciates also the value of the scientific approach to that subject. The action it has taken by the appointment of the Economic and Social Advisory and Planning Council is in itself an evidence of that appreciation, and in the same spirit it sincerely welcomes the fact that this Science Association is applying itself to the subject along the lines of a procedure which has on previous occasions proved to be exceedingly productive. I have not the slightest doubt that this Symposium will also yield very valuable results.

We commence of course with the fact that war has an essentially dislocating effect. One of its results is that most of our links with the past are snapped—habits, ways of life, customary modes of thought are altered—changes are made in the industrial and commercial fabric—modifications are brought about in the relationship between different elements of the community. But in time, war gives again place to peace. In anticipation we think of the return to peace as a return to the old life—but the old life can never be entirely reconstructed. Indeed it is as well that it should not be. Changes there must be in post-war conditions as compared with pre-war conditions. Moreover when the war is a total war as is the case to-day, these changes are inevitably of a radical character.

From this it follows that in our anticipations of the post-war world we should think not so much in terms of repairing the dislocation caused by the war, as in terms of the building of a new and better world, a new and better South Africa.

Well, of course, it is easy, it is a pleasant occupation to paint pictures of a new and better world, to prepare blue-

prints of Utopia. It becomes far more difficult, far less pleasant to relate our planning for the post-war period not only to the realities of the present, but also to the still undetermined realities of the future.

As a politician I am conscious of the facility with which statements can be made about the post-war world, statements of which the main aim is to arouse in the audience a pleasant sense of anticipation. But, especially if one is in a position of responsibility, one reflects on the importance of determining at this stage when the war will end and what the world will be like when it does end. One recalls also the harm done during and after the last war by promises of the "homes for heroes" type. One remembers that war is in the first instance a destructive process, and that therefore if there is to be a better life after the war, the crux must be the utilisation of our productive resources much better than in the past, and that in doing that we shall have to start with the disadvantage of having first to repair the consequences of the destructiveness of war.

But the scientist's approach to a problem is objective. He is not concerned with giving pleasure to his audience. He keeps his feet ever on the facts of realities. If he puts forward hypotheses, he is concerned with the likelihood of their working. So he blends realism with idealism, and that is the first essential in dealing at this stage with the question of post-war reconstruction.

The chief task of the Chairman to-day is to see that the time-table is adhered to. I must treat myself as ruthlessly as I treat others. I shall therefore deny myself the luxury of a peroration and get on immediately with the work.

(3) THE INDUSTRIAL ASPECT: PRESENT

BY

DR. H. J. VAN DER BIJL.

Chairman, Electricity Supply Commission, etc.

I must congratulate the Council of the Association on arranging this symposium. It comes at an opportune time and is obviously intended to assist the Government in the great and vital task it has set itself of inquiring into ways and means of directing and assisting in the future industrial development of our country.

In planning for the future we must not forget that this war must first be won before our plans for the future can be of any effect, and many of us are so fully occupied with the war effort that future planning can only be done in the very

limited time at our disposal. What we must do, and can do, is to watch the effects of our industrial war effort as well as the general industrial position, especially the difficulties created by the war, in the hope of finding the sound guidance that will be necessary for formulating our future plans.

We are in a much better position to-day to plan our future than we were at the time of the last Great War, because we now know much better what South Africa is capable of than we knew then. Although planning during the past twenty years has not been comprehensive, it cannot be said that South Africa's present industrial position is entirely the result of haphazard growth. For example it was just about twenty years ago that the Board of Trade and Industries was established and it has certainly exerted a measure of stabilization on our industrial growth. This was the first recommendation I made in my then capacity of Industrial Adviser to the Government. The organization of South Africa's power supply industry and the fostering of the iron and steel industry on a national scale were also milestones in a carefully engineered road leading to a sound industrial future.

What I believe is going to be a factor of very far-reaching influence in shaping the destinies of our economic future, namely the Industrial Development Corporation, is to-day unfortunately still in its infancy. If the Government could have seen its way to establish this Corporation when I first suggested it in 1934, South Africa would have been in a much less uneasy position than it is to-day. I use the word "uneasy" because the extent to which many of our industries still depend on imported raw materials especially of a semi-manufactured type is, under the present difficult shipping position, distinctly disquieting.

However, there has been sufficient industrial development during the past twenty years to make possible the framing and adoption of a vigorous plan not only for the rehabilitation of those who have sacrificed their careers in the defence of their country but also for building our national economy on a permanent foundation.

The greatest encouragement I have ever experienced—and this should be a heartening encouragement to all South Africans—is the remarkable skill and ingenuity of South African engineers as evinced by their achievements in our war supplies effort. What they have done will—if the story could be told—be incredible to those who know of similar work in other countries. I have always regarded brains as a country's greatest asset. Our war effort has shown that we can plan boldly, knowing that South Africa will have the brains to carry out the plan.

Until the war is over, particulars of our war effort cannot be published in sufficient detail to demonstrate the remarkable

ability of South African engineers, but I can give a few examples to indicate that we can plan without making ourselves guilty of acting like the proverbial fools that rush in.

Guns were planned, tooled and produced in much less time than we know of anywhere and every ounce of them including bullet proof tyres were made in South Africa; to meet the special steel requirements for armaments no less than 120 different types of special steels never before made in South Africa are being manufactured including high speed tool steel. Automatic machines for making small arms cartridges were made in large numbers and that without any drawings to start on; mortar and gun sights, things that were quite out of South Africa's range, are being made in large numbers, and thousands were supplied to England; Iscor's number three Blast Furnace and the Ferro-alloy Works at Vereeniging were built almost entirely in South Africa; so with automatic shell forging plants which were built and put into operation in exactly half the time given for delivery from abroad; aircraft hangars, measuring 125 ft. by 95 ft. by 25 ft. to the eaves, which before the war took from four to six weeks to build, have for a long time been turned out at the rate of thirty complete buildings per month. When a review was made last October of our industrial war effort it was found that South Africa had actually produced more of certain types of shells and bombs than either Canada or Australia. Our armoured cars which are a hundred per cent. South African design have become famous and amply share in the credit for the conquest of Abyssinia. Our design of army boots and blankets, with their envied fame abroad, run into seven figures, and we have already turned out close on to half a million spare parts for tanks, other vehicles and aircraft.

I hope I did not bore you with all this. This list of achievements of the South African engineer could be multiplied many times. I have given a few examples to indicate that from the technical point of view South Africa is ripe for a forward industrial policy. But what of the Governmental, economic and sociological sides of the problem? In those fields we are to the same extent still groping in the dark.

In the first place let us not be side-tracked by the argument that vigorous industrial development would tend to make us self-sufficient to the detriment of our gold mining industry. I have dealt with this question on previous occasions and cannot discuss it again in the limited time at my disposal except to mention two points, namely, that no matter how we develop in other directions our gold mining industry will, as long as it continues on a big scale, be a factor of tremendous importance to our economic well-being,

and this fact will not be affected one iota by development in other fields. Secondly, what I have always contended as almost obvious is that the more we manufacture the more we increase the affluence of our people, with the result that our imports must increase. Our industrial history during the past twenty years has proved this.

As regards Government and individual or private effort I firmly believe that we cannot hope for sound development unless the Government and the people march hand in hand on the same road to the same goal. This war is going to force many unexpected changes upon us. We must try now to anticipate some of them at least and to be prepared to adopt them in a manner that will bring the greatest possible measure of benefit to our people consistent with sound national economy. Even the conception of Government and its relation to the people which we have drifted into, perhaps unconsciously, will probably change. This drifting has, I believe, been brought about by excessive political development. Political exigencies must under our present system of Government carry weight but they must never weigh more than to comply with Lincoln's definition of "Government of the people by the people for the people." By people, I am sure Lincoln must have meant the people as a whole. What will come and must come is co-operation in the form of a closer merging of the Government and the leaders of thought and action in commerce, industry, agriculture, mining, labour, sociology and health—in short, all the branches of activity that make up our economic structure. I may, without further discussing the matter, exemplify it by saying that our industrial war effort could never have achieved what it did but for the policy I followed from the start of calling in for guidance, advice and assistance, the leading men in all the phases of activity that enter into this huge nation-wide and comprehensive organization. I did this because I know the limitations of my knowledge and I respect the expert knowledge and experience of others.

Time does not permit of more than a brief mention of some of the fundamental problems we shall have to face squarely, in the light of our knowledge of present conditions, before we can hope to see the realization of any plans we may formulate.

Of these problems perhaps the most important is the sociological problem. It is a problem to which I have given considerable thought for several years in connection with my industrial undertakings. The experiments which I have so far conducted have given me a fairly clear indication of the direction we should follow, and recent researches carried out by competent men, such as Dr. Cluver and Dr. Jokl prove

that no amount of consideration of this problem can be too much. Our effective population can be very considerably enlarged by making better provision for and increasing the productive capacity of our natives and unskilled whites. These people do not ask for charity, which in any case would be demoralizing. They want, and are entitled to, opportunity. It is, for example, not a matter of merely paying natives higher wages but of giving them the opportunity of earning higher wages. This also applies to a considerable portion of our white people who are precluded from doing what is really semi-skilled work because it happens to be classed as skilled work. The solution of this problem is not only of the utmost importance, it is urgent. No matter from what angle we view the peculiar difficulties in the way of our industrial development, be it from the point of view of the level of our price structure, or of customs protection, or of the international purchasing value of our currency, the root of the matter is found on final analysis to lie buried in the desert of unfairness to the semi-skilled and unskilled section of our population. This incompatible position calls for immediate review and early revision. Year by year, even day by day it is getting worse. For the sake of posterity we might as well face the music now. This problem is so wholly peculiar to South Africa that we cannot look to any other country for guidance. Its solution requires the best brains of South Africa and the sincere co-operation of Government, employers, employees, and not least of Trades Union leaders. These last named have, to my knowledge, been through a difficult school and have become very able guardians of their section of labour. Their knowledge and experience can be of considerable help in agreeing on a solution that must obviously redound to their benefit as well as to that of other sections of the community.

Merely to house these people in a manner that will not call forth disparaging remarks from overseas visitors will require industrial activity on a large scale, not merely in the building of the houses which will number hundreds of thousands, but also in the manufacture of so many items that can be made in South Africa and which go to make a home. The problem of housing the less fortunate people in South Africa cannot be as difficult as in a country like England because we have the climate on our side.

The Government made a good start before the war by advancing money at low rates of interest, but this is not enough. Engineers and architects must reduce the cost of building and so help the Government. Again they must march hand in hand.

One of the most important pillars on which our industrial structure must rest is base minerals. We are not so well endowed with these as we are apt to believe. I know this

from bitter experience. The three great basic minerals are of course iron ore, coal and lime. This country can be said to be full of iron. Even the highest grades occur in very large deposits, but although we have large coal deposits very little is suitable for iron making. You may be surprised to learn that one of my greatest difficulties at the time of establishing Iscor was the absence of suitable lime in sufficient quantities. Fortunately large deposits have since been discovered but it required a lot of searching. What can be said generally of our base mineral deposits including manganese, chrome, wolfram, magnesite, etc., is that in most cases we know only of large deposits of poor stuff and in some others the occurrences are distinctly potty. The quantities of minerals that can be used directly in our metallurgical industries are not large. The export of this grade should be prohibited. This will be the job of the Government. On the other hand it will be our job to carry on the research and solve the problem of making the poor stuff usable.

While we are on the subject of raw materials let me express a view to which my own industrial activities have been leading me for a considerable time past. It is that in framing industrialization let us not think of the Union only. We must contemplate a comprehensive African development. Let us not follow the example of some of the older countries by trying to grab all industry for ourselves even though we have not the raw materials therefor.

It is not possible to deal with this large question in this paper beyond saying that I know of industries that should be established in other parts of Africa and not in the Union if we take the long and sound view. South Africans should establish them. Only ten years ago I never dreamt of South Africa becoming a creditor country for generations to come. We are fast heading for it now and we shall soon be faced with a new set of problems in the solution of which our gold mining industry can be a more permanent tower of strength than it has ever been in the past.

In conclusion let me say that I do not believe in planning to the extent of placing the onus on the Government to do everything for us. That is not the Government's function. The Government's job is to create conditions that will encourage enterprise, not of the type that results in the unfair enrichment of some at the expense of the others but enterprise that results in equitable distribution of benefits. But planning we must do if we wish to reduce national economic waste to a minimum, planning that requires co-operation between the Government and the people, that will make it possible for Government and people to march hand in hand.

(4) THE INDUSTRIAL ASPECT: FUTURE

BY

DR. H. J. VAN ECK,

Managing Director, Industrial Development Corporation.

I agreed to take part in this symposium on post-war reconstruction because I believe that the war can be fought much more effectively if everybody were to take stock very clearly, now, of the objects we are fighting for. The peace and the shape of our post-war economy will be moulded largely by the ideas formulated during the war. It has taken us a very long time to adjust our economy to war needs, but I know that very much greater adjustments will still be necessary in South Africa before we finally sit around a peace conference table.

We have already had to submit to controls in various directions, but we shall have to submit to still more controls in the future; the efforts of individuals will need more and more direction in the interests of the community during this period of emergency. After the war it will require more directive effort and co-operative planning to reconstruct the world in which we and our children are going to live than we have been accustomed to or than we have applied up to now in converting our economy to war conditions. Although our men are giving their lives in the front line of battle, there still seems to be an atmosphere of unreality in South African economic thinking and production programmes.

Our limited resources of raw material and labour are not as yet applied as fully as possible towards the production of those things which we need most urgently in waging the war or in the production of materials essential to the maintenance of the civil population on a war time basis for several years. Owing to the regular maintenance of shipping communications with the outside world for so many years, the people of South Africa have become so accustomed to being able to obtain their essential needs as long as they have had money, that money has become synonymous with real wealth. They have not yet realised sufficiently that if the ships are not available to bring essential goods to our shores, our money will be of little use, and too much of it in circulation in relation to the amount of goods available in the country may even upset all our ideas of prices and social security. With these thoughts as a background, I shall attempt to give you an engineer's view of the future of South African Industry.

In framing the future industrial policy of the country, the deciding factor in my opinion must be the welfare of the

greatest number in the State. I believe that in peace as in war, full employment of all the human resources in the country should be our most important guiding principle in order to satisfy the everyday needs of the population to the fullest extent. The purpose, therefore, of our national economy should be to increase the national income, in which everybody will share, and thus steadily raise the material and cultural level of the whole population. In order to attain these objects it is essential to increase the productivity of all labour by applying the most modern scientific and technological developments, including, of course, the fullest use of power driven machines.

The mapping of a future programme for South African Industry will, therefore, resolve itself very simply and directly into a careful study of the essential needs of the population in the form of food, clothing, housing, education, recreation, transport, medical services, etc.

In order to satisfy these needs it will be necessary to make a careful survey of the natural resources available in the country, and a careful consideration of the best methods of using these resources to the advantage of the community over as long a period as possible.

In the production of any commodity care must, of course, be taken that the opportunity to produce other things of greater value with the same resources is not lost. It follows, therefore, that we shall produce in the country those products which we can produce most easily, we shall export those surplus goods which we can produce more readily than other Countries, and in turn import the goods which other Countries can produce with less effort than we can. The industrial production programme will therefore be decided largely also by the relative amount of effort that is needed to produce the various types of commodities. These conditions will apply in a peaceful world and with free availability of shipping. If shipping is not readily available, every effort must be directed towards producing in the country the goods needed directly for the maintenance of good health and the maximum productivity of the population. Every other consideration then goes by the board.

In addition to a survey of the natural resources, it is necessary to make a proper survey of the human resources in the country, and the best way in which these human resources can be trained to productive employment. We know that by the application of scientific and more pleasant methods of training, the skill of the individual can be improved very much more rapidly than by following the old haphazard methods of leaving a boy to pick up as much of a trade as he can while often engaged in soul destroying repetition work.

I submit that by following the above very straightforward programme for South African industry, we need fear no post-war depression nor unemployment, as we shall consciously be planning for plenty for ourselves. Any restrictive dog in the manger outlook on the part of sectional capital or labour or of any producer of essential goods must not be allowed to disturb the drive for increased consumption. The main limiting factors can only be the proper utilisation and husbanding of our natural resources. We must not be diverted from this path by worrying about where the money is to come from. When a man works he makes money. His wages or salary is only a measure of the work he has done and enables him to claim from the community an equivalent measure of the goods needed by him and produced by others. As long as men and women are available for engagement in some form of production needed and sanctioned by the community in order to maintain and extend the well-being of the whole in accordance with a definite plan, the supply of money need not be a limiting factor in production. As Scientists who accept the Law of the Conservation of Energy and fixed standards of measurement of energy, we should, however, be very much concerned as to whether the unit of money does indeed represent a satisfactory and constant standard of measurement of human effort.

In order to be able to draw up a full programme for industrial development, it is necessary to have an expert planning body co-operating with all sections of national thought. We have already decided on a mild form of national planning in South Africa, by the appointment of the Social and Economic Planning Council, but we still have only vague ideas as to how the thoughts of the ordinary citizen can be crystallized in such a manner as to culminate in a final project. It is still necessary, therefore, to work out a technique of planning for South Africa.

It is obvious that one of the most important factors in the technique of planning must be a properly organised Research Plan, and naturally Scientists are in the best position to formulate and submit such a plan to the Central Planning Organisation, which can then co-ordinate the Research Scheme with its other activities. May I here appeal urgently to scientists for their co-operation in formulating such a scheme for organising Research in the Union of South Africa, in order to assist in planning the programme of industrial expansion which we visualise for the future. We are all agreed on this: we have spoken a great deal about it: can we get down to practical realities now and prepare a scheme.

Before giving you some of the more specific directions in which I think South African industry should and will

expand, I must indicate the geographical limits within which South African enterprise can operate and shortly the manner in which I think it should operate. The war has taught us and our neighbours in the Southern half of the African Continent how dependent we are on shipping for our well-being, and how we can assist one another in the interchange of essential materials. Unfortunately, we have found that we are ill equipped for this interchange of goods, due to inadequate transport facilities, and inadequate information about our respective needs and capabilities.

Although South African secondary industries are still extraordinarily dependent on overseas raw materials, we were rather over-optimistic a year ago regarding our ability to sell manufactured goods in neighbouring and Northern Territories. We were inclined to overstress this selling angle instead of also concentrating on satisfying their real needs as well as on what we could purchase from our friends. I think that Africa South of the Equator will be found a very satisfactory geographical unit within which economic interchange of vegetable, animal, marine, mineral and manufactured products can take place.

As the Union is the furthest advanced, industrially, of the countries in the Southern portion of the African Continent, we should look to other African Territories mainly for the supply of raw materials instead of going far overseas as in the past. This emphasizes the need for very much improved transport facilities, including coastal shipping, which, incidentally, would fit in very well with a small local shipbuilding industry, and with the development of our fishing industry. In thinking of products which we can export in order to pay for raw material imports from neighbouring territories, one naturally thinks of those materials which we can produce to best advantage. In our case this happens to be gold, which is the same as money, so that it follows logically that we should be essentially buyers from our neighbours and not sellers of manufactured goods. I submit that such a change in our trade policy with other African Territories will assist greatly in stimulating trade and good feeling. The market for our own manufactured goods must be found mainly within the Union until such time as our policy of buying from the North and improvements in our production efficiency have made it economically possible for our friends also to purchase considerable quantities of commodities from us.

The most important industry in South Africa in value of output is the food and drink industry, and this will always remain the most important industry to the people of this

country. I think that there has been too little co-operation between the producer, the manufacturer, the distributor and the engineer in the interests of the consumer. It is generally accepted that everything must be done to stimulate animal husbandry in South Africa, and that from a nutritional point of view the nation as a whole must consume more animal products. With this object in view, therefore, it is only reasonable that very much more attention will have to be paid to the feeding of animals in order to feed human beings more efficiently; the production of a scientifically balanced ration for animals will, therefore, become a very important industry indeed in the future. In addition to cereals, such an industry will process certain vitamin products, and considerable amounts of meatmeal, fishmeal, bonemeal and plant protein in the form of various types of oil cake. In the Territories North of the Union there are considerable quantities of oil-bearing seeds available, such as cotton seed, palm kernels, etc., from which we can obtain the oil cake essential for the maintenance and development of a large and high grade animal population, in addition to the vegetable oils needed in the food and chemical industries.

In the distribution of meat it seems reasonable to think in terms of a properly designed central abattoir strategically situated in the centre of the most suitable animal producing area so that the most efficient use can be made of offal products in the immediate surroundings as fertilizer, or animal feeding stuffs in the form of bonemeal. One visualises the sale of carcasses at standard prices based on careful grading, the rapid conversion of carcasses into standard cuts which can then be frozen by modern quick freeze methods, packed and transferred rapidly in freezing trucks directly into the frozen larders of grocers shops, where the housewife can purchase the standard cuts of her choice. A great deal of unnecessary and unhygienic handling can be eliminated in this manner.

In the future one visualises the possibility of milk being brought to some central depot in a city, there pasturized if necessary, and delivered in a rational way to householders: in order to provide the proper utilization of this very valuable product, it might be necessary to attach a cheese factory or a dried milk plant to the central depot, in order to provide proper stabilization of the surplus for use as an alternative food when there is a seasonal shortage of milk. These few remarks will suffice to indicate the need for very bold thinking and planning by scientists, engineers and producers will be necessary in the future in order to simplify and rationalise our food production and distribution system.

An American paper recently reported the launching of

an air freighter capable of carrying 9½ tons of freight, or approximately fifty men. It was estimated that twenty-one of these air freighters by making three trips per day could replace the 4,500 trucks that used to ply the Burma Road, one plane thus replacing 218 trucks. While I am not in a position to confirm the correctness of the above estimate, you will agree that the long range and the speed of the aeroplane will make the world a very much smaller place. We shall have to change our ideas very considerably regarding transport after the war, and towns will have to be planned so as to accommodate aerodromes within their boundaries. I understand that the War Production Board of the United States of America has already suggested that the very large stock of nickel steel alloy moulds and dies used in the pressing of motor-car bodies should be turned into scrap metal for the production of munitions.

The destruction of these moulds and dies, valued at about £15,000,000, would ensure a completely new field for the post-war designer of motor cars. It would turn the present models into worthless antiques even more surely than war time rationing of tyres and petrol. It is further estimated that within 2½ years about fifteen million motor cars in the United States of America, or more than half of those now in service will have become converted into scrap. The production of the light metals, magnesium and aluminium, has increased enormously during the war. These light metals together with a simplified technique in casting and forging will revolutionise the production of the internal combustion engine as well as that of the motor car itself. One can, therefore, visualise the future motor car as a vehicle weighing less than half that of the present motor car. Plastic materials will play a very important part in its construction just in the same way as opaque and transparent plastics to-day play a very important part in the manufacture of aeroplanes.

Serious doubts have been cast on our ability to maintain our present standard of living due to the future inability or unwillingness of large sections of our population to work so hard in order to maintain it. We may, therefore, in the future have to pay very much more attention to one of the most important factors in maintaining the value and efficiency of a motor vehicle, namely, the road itself. A good even-surfaced straight road is a permanent asset to the country, while there is usually very little left of the motor vehicle after a few years. I think, therefore, that we shall be forced into a programme of very good roads all over the country in order to accommodate the smaller model motor car fitted with small wheels in order to maintain a low centre of gravity and to save on rubber.

It is obvious that all forms of transport will have to be

very closely co-ordinated, and our future transport organisation may agree that it is very much easier to pump petrol and oil from the coast to the interior through a pipe line than to send it by tankcar. A recent development in the United States is a railway train which can switch from steel wheels on an ordinary railway line to rubber tyred wheels capable of running on the streets. This scheme which saves handling, can, of course, have only a limited application, but my previous remarks will indicate to you how our important transport and vehicle industry may be changed in the future, and how careful we must be when considering at this stage large scale schemes for the building of railway carriages, wagons and locomotives.

The petrol engine has developed to an amazing degree of efficiency and cheapness—in the best aeroplane engines the ratio of horse power to weight expressed in pounds is already just under one. Too little attention in the past has been paid in South Africa to the possibility of adapting locally available fuels such as bituminous coal and charcoal for use in the cheap petrol engine, by means of a suitable attachment, such as a gas producer. Some of our future locomotives drawing light metal or plastic coaches may even be internal combustion engines using, say, producer gas made from bituminous coal.

Next to the food industry, the engineering industry is our most important secondary industry in the Union. The development of the light metals and of plastics will open up undreamed of possibilities in all forms of construction. This will not mean that steel will become obsolete; I personally believe that the Steel Industry has a very great future indeed in this country, but it will certainly be necessary for steel to meet the competition of lighter metals. Fortunately we are well situated in this country for meeting this competition. We can produce high grade alloy steels, which will compete in weight, strength and utility with the light metals, from our extensive local supplies of chromium ores. South Africa is fortunate in possessing enormous quantities of chrome ore, though it is not of the highest grade. The production of ferro-chrome, chrome steel and chromium alloys could be developed into one of the most important industries in the country. Special processes can be developed locally on the basis of the relatively cheap ore instead of blindly following the methods adopted by other countries, which have naturally been influenced by the high cost of the imported ores. Just as a world market for nickel or aluminium has been developed, so a very much greater market can be developed for chromium and chromium alloys than exists at present. In addition to the possibilities of markets on the African Continent for all kinds of stainless steel goods, one

has visions of exports to countries even further afield. Altogether too little attention is paid by the state or the community to research work in developing the local utilisation of our minerals, such as chrome ore and manganese ore. We have spent enormous sums on research in agriculture, rightfully so in my opinion, but similar sums will have to be spent in research on the development of some of our other raw materials.

In munitions production considerable quantities of non-ferrous metals like copper and zinc are being processed. The plants now in use will after the war form a basis for an extensive non-ferrous metal industry in this country.

While unable to give a complete survey, I cannot avoid mentioning the essentiality of a large textile industry. Clothing is one of our basic needs, and we have both cotton and wool available in the Southern African Continent. The Northern Territories are already making extensive plans for the spinning of cotton, utilizing African labour; what is our attitude towards these developments? We shall have to initiate similar schemes in this country, in order to be able to satisfy our essential needs ten years hence, if not very much earlier. In the development of these new industries I believe that technological improvements in mass production methods are of very much greater importance in bringing down the costs of production than the unrestricted functioning of the competitive system. In other words it is a wasteful use of national resources to allow the erection of two factories each operating at half capacity at a high cost, when one factory could supply all the country's needs at a much reduced cost. Such a single unit will, of course, have to be subject to control in some manner in order to prevent exploitation of the consumer. For South Africa, therefore, I visualise some form of industrial licensing in order to ensure efficient industrial development. Efficiency audits could easily be introduced in order to keep efficiency at the highest pitch. The production of artificial fibres already exceeds the world production of wool. We may in due course find that we are not so favourably situated regarding one of our main items of export. Fortunately we are well situated in having extensive coal deposits from which the production of plastics and artificial fibres may in due course be developed.

We are too prone to regard post-war conditions in the light of what we have been accustomed to in the past. Behind the curtain of wartime secrecy very many great discoveries are being built up during this terrific struggle. These discoveries will burst upon a post-war world with a force that cannot now be estimated. New methods and new ideas will be applied to production problems after the war. It is, therefore, essential to organize our thoughts and productive

systems in such a manner that we can take advantage very easily of the very many new ideas which we shall have to follow during and after the war. In a storm it is best for a ship to ride it out in the open sea; there is no great danger if the ship is well built. Let flexibility and adaptability be the guide in building our craft of state which is to weather the economic storms of the future. It is, therefore, necessary to organize the training of youth in such a manner that it can think dynamically in terms of rapidly changing world conditions and their effects on South Africa.

(5) SOME AGRICULTURAL ASPECTS OF POST-WAR RECONSTRUCTION

BY

PROFESSOR H. D. LEPPAN.

From 1921 up to the present war, agriculture has been in a bad way in all countries. The reasons for that situation are not far to seek, but as these have been fully described in a number of published treatises they need not be detailed here. For our purpose it is necessary to remember only what the chief contributory causes were. The almost universal urge towards national economic self-sufficiency obstructed trade channels. Behind tariff walls, most countries seemed determined to be self-contained in case of war. Suspicion caused the drying up of international loans and closed economies were the order of the day. Unemployment reached unprecedented proportions. While the situation was largely aggravated because the increased supply—produced by improved technique—encountered a relative decrease in effective demand due to a retardation in the increases of the Western world's population, it was also due to the mal-distribution of wealth which prevailed.

To remedy the situation State intervention became the order of the day, and in some countries control measures of a Gilbertian nature were taken. Coffee was thrown into the sea; maize was used as fuel; cotton was ploughed up; restrictions on production involved, among other steps, the destruction of a proportion of animals at birth; and so on. With a relatively large export trade in farm products South Africa was obviously unable to immunise herself from the world disorder and was, therefore, compelled to undertake drastic remedial measures if the rural population was to be retained on the land—an important plank in the platform of any political party in the Union.

As in the past, so in the future, South Africa cannot isolate herself from the repercussions of trends in other parts of the world. The future lot of farming, both here and abroad, must depend largely on the extent to which the intentions underlying the Atlantic Charter are put into effect. If by international agreement, involving a lowering of tariff barriers, the development of resources favouring the comparative advantages of various countries is fostered, an enormous advance will be made in stabilising and improving the prospects of farming. In some countries the internal economy will have to adjust itself rather drastically to conform with the export demand so established, and consequently the transition period may involve a measure of hardship. But the effort spent in surmounting the difficulties of this phase will be more than compensated for by the increases which would eventually follow in the national dividends of the various countries. Incidentally, in the case of South Africa, the result would be that the country would concentrate in her export trade on some of the animal products—particularly wool—and eventually the importation of wheat and maize would follow. In this event the possibility of maintaining our soils would be greatly enhanced.

While South African agriculture receives less State aid than do the manufacturing industries it is nevertheless rightly held to be the sick organ in the country's economic body, for in spite of the assistance given in past decades it is an industry prolific in the production of indigents and most wasteful of the Union's chief material resource, namely, the soil. Further, whatever the reason may be, the fact remains that in the economic activities of the Union only about 12 per cent. of the national income is earned by approximately two-thirds of the entire population. In planning for the future, then, cognisance must be taken of the necessity for a redistribution of the population.

While a desirable redistribution would have encountered difficulties some years ago it is now faced by added problems. The uncertainties regarding the economic resources which will be available at the end of this devastating war make an intelligent anticipation of the post-war period highly speculative. Far less blurred, however, is the position with regard to gold mining—the industry which has hitherto made possible the State assistance given to the secondary industries and to agriculture, and which until recently was considered to have an indefinitely long life. It now transpires that a very rapid waning in the production of gold will take place in the very near future. This disquieting fact alters the whole outlook from that of a few years ago. Manufacturing and the mining of base minerals will have to be developed as rapidly as possible and it is extremely doubtful whether this development could take place on sound lines fast enough to

make up for the loss in the national revenue due to the decrease which must take place in gold mining. Indeed, on reflection, it is difficult to see how a lowering in the standard of South African living of many can be avoided. Certainly, in considering agricultural post-war reconstruction this general feature of the Union's future economic structure cannot be ignored, since the measure of the past generous State aid to farming will not be possible in the near future, nor will the secondary industries be assisted to the former extent. From the above discussion it must be clear, firstly that the townward movement of what were considered to be redundant rural people cannot take place as rapidly as was previously thought possible; and, secondly that farming will have to look more to itself for its own salvation.

Before considering the optimum utilisation of our resources in rural land some comment on an aspect connected with that of labour should be made. Our supply of labour is not unlimited. What labour is available is undermined numerically and qualitatively by malnutrition and a lack of adequate training. The natural shortcomings of a country can be overcome to a considerable extent by increasing the efficiency of its labour. The validity of this statement is borne out by a country poorly endowed physically for mining or farming like Switzerland where despite these disabilities a high standard of living has been maintained for many generations. The obvious fact that efficient labour can produce more wealth than inefficient labour is too often overlooked. Rendered efficient through adequate food and proper training labour can be paid more and so the purchasing power of the lower income groups is raised. This aspect, then, has a very direct bearing on South African farming because of the increased demand for its products, especially foodstuffs, and because of the economies which can often be effected in internal transfers of perishable products rather than the external exchange of these products. This market so created would be invaluable to our farmers in the disposal of commodities below export standards or those demanded by the higher income groups. A start in this direction would lie in subsidisation ensuring the proper feeding of the poorer sections of the community, for obviously physically under-developed human beings are incapable of acquiring the best out of training.

With the methods too often hitherto practised in our farming the economic pressure on the land has probably been the chief cause of the abuse and consequent loss of our soil. To meet their commitments farmers have striven for the maximum output rather than the optimum and so have neglected the safeguards demanded by the soil. As with other regions of the world where the soil becomes desiccated

over long periods of the year, erosion remains a serious menace to our agricultural resources. And yet in spite of this threat our rural land will have to contribute a higher proportion to the national income than has been the case in the past. Obviously, in planning post-war reconstruction boldness in dealing with the problem will be necessary. If a great many farmers remain indifferent to the wastage of this national asset, resort to compulsion in some form or another will be necessary. This may necessitate measures prohibiting injurious practices. But perhaps one of the most effective ways of remedying the situation would lie in the nationalisation of some of our land. In the main it is the farmer in desperate financial circumstances who by over-stocking does most damage to the soil. Nationalisation could be ushered in on a voluntary basis on land acquired from these farmers by the State and leased on a 99 years' tenure. The long lease would give the tenant much that is desirable in ownership, but more important is the fact that controls could be exercised to check malpractices in the use of the land. In parts some enterprises would be prohibited; a limit to the number of animals would be imposed; land, of too steep gradient, would not be allowed to be ploughed; and so forth.

The agro-economic survey started by the Department of Agriculture and Forestry is a step in the right direction. When completed this will give guidance to the best enterprises to be undertaken in the various districts; the size of the unit required for farming; the price which should be paid; and so on. It is hoped that when the work on this survey is again resumed it may eventually lead to a Land Utilisation Bureau where the whole question of the optimum use of land would be studied. As a guide, not only to established farmers, but particularly to settlers, a Bureau of this nature would be invaluable.

In scrutinising the reasons for the many failures in the settlement of South African land, the following appear to be the most prominent. Sufficient discrimination was not shown in the selection of settlers. Too often men were put on the land who were unsuited to farming or who had previously shown themselves to be incompetent as farmers. What preparatory training was provided was often inadequate and little proper supervision was given, so that enterprises unsuitable to the area were often undertaken through a lack of experienced guidance. Many were placed on irrigated land which is always an exacting type of farming to be learned either by long experience or by well-trained, intelligent settlers. Unfortunately those placed under irrigation made cereal instead of animal farming the main-stay of their operations. In fact cultivation was over-

emphasized, and animal husbandry—for which the country is better endowed—was neglected. Too often the inexperienced settler spent too much of his capital in acquiring a large area of land and consequently failed because of inadequate working capital. Here it might be interjected that under schemes promoted under State ownership this disability would be overcome. But perhaps the chief reason for failure lay in the purchasing of low-priced land by settlers, for such land is usually low-priced for good reasons, e.g. diseases and precarious rainfalls, and is seldom cheap. Political motives, too, have added their quota to the failures of the past. These exhibited themselves in uneconomic irrigation schemes or often in placing settlers on farms too small to earn a living in that particular area. Fortunately, to-day, especially under State auspices, the reasons for past failures are well known and constructive steps are being taken as safeguards. In general, however, it should be remembered that farming in the Union, because of the many natural disabilities of the country, is no easy calling.

The aim of many misguided enthusiasts seems to be that, whatever the cost, all of our rural land should be farmed. They overlook the fact that maize and meat are not the chief products from land and that these are of far less importance than the production of healthy citizens. Indeed, it can be argued that some of our disease-stricken areas, both for animal and humans, could be withdrawn from farming and better used nationally as game reserves to attract remunerative tourist traffic.

Those concerned with post-war reconstruction should realise that hardships on South African land will continue to be all too common unless the country's foundations for development are properly planned. The more closely farming is fostered in conformity with the dictates of the natural controls the more likely is it to succeed. It must eventually prove folly to continue longer than necessary to stimulate cereal production in a country where most regions are better suited to animal production than to grain production. Such a policy leads to the loss of soil, to the impoverishment of the farmer and engenders instability in the economic structure of the whole country.

The past decade has seen a marked increase in State intervention in the affairs of organised agriculture, evidence of which is to be seen in the establishment of the various marketing control boards whose existence has annoyed many vested interests. The operations of these boards are still in the exploratory stage and at present room for justifiable criticism may exist. However, with the powers given under the Emergency Act and those of the Food Controller bolder measures can be taken than existed under the Marketing Act

In consequence it is hoped that improvements in marketing will be brought about and that the experience gained will assist in evolving controls of a more satisfactory nature which will assist in stabilising the outlook of South African agriculture. The dispersed nature of farming units makes collective action by farmers difficult, and, while the co-operative movement has been of some assistance, it has not been able to cope with the situation fully in South Africa. The alternative of statutory control boards working in conjunction with co-operative bodies seems to be a feasible solution and is one which should be considered in post-war reconstruction. It may be argued that monopolies so created are undesirable, but this can be countered by saying that effectively controlled monopolies give immense economic advantages, particularly in agriculture where the imperfections of unrestricted competition are so glaring. The establishment of these boards is a new departure and consequently properly qualified officers to direct their activities are hard to find. In the education and training of the right type the universities could be of real help. In the meantime it might be conceded that the system may not be the most economic; however, it cannot be gainsaid that what small economic loss there may be at present is more than offset by the social gain.

In a short address of this nature it is impossible to cover the whole field in all its ramifications. Apart from those indicated, two aspects affecting farming should be explored when considering the position after the war. It is now recognised that the keystone to the arch of the Union's farming lies in the animal industries of which meat production is one of the most important, and yet the marketing of meat remains in a chaotic state. In the Reef-Pretoria area there are a dozen municipal abattoirs and about thirty private slaughtering concerns. Obviously the economies of large scale production are not nearly as effective as they would be in a centralised plant, nor can the valuable by-products be exploited to the full. The whole industry should be placed under some form of utility corporation. Economies would be reflected in the producer's price; distribution would be more orderly, and the meat industry would be stabilised. If put on a satisfactory footing the meat industry would rectify many of the maladjustments in our farming, e.g. the exportation at a loss of surplus grain, dairying in localities not suited to dairying and the unnecessary wastage of our soil resources. The other direction in which farming could be enormously assisted lies in road construction. The assistance of good roads in lowering the costs of production in farming and in improving distribution are not sufficiently recognised. Much has been done in this direction by the building of national highways but much remains to be done

particularly in the Native areas. Nor should the permanent employment be overlooked which will be required in the proper maintenance of the country's road system when construction ceases. The maintenance of roads in the future will require a permanent staff somewhat analogous to that of the railways.

Our discussion, if in the main correct, leads to the inevitable conclusion that post-war reconstruction must conform with the framework of a well thought out plan for the future economic structure of the country. Without this guidance many of the best intentioned schemes are bound to end in futility or in unnecessary hardship. Fortunately the recommendation of the Industrial and Agricultural Requirements Commission that an Economic and Social Planning Council be established, has now been implemented. This is a departure of the utmost significance since for the first time we have a body "responsible for exploring all directions for the orderly development of the Union's resources and for submitting a sound basis for formulating national policies on social and economic matters." In consequence we can confidently look forward to a constructive policy of a continuity impossible when left entirely to changing Cabinets.

(6) TRADE UNIONISM OF THE FUTURE

BY

A. J. DOWNES.

In the first place I want to thank the Association for giving me this opportunity of submitting the Trade Union point of view on this question—a point of view which perhaps is not often brought before the Association. My one regret is that the time allowed is not sufficient to do justice to the job, but I will do my best in that limited time.

Secondly, I would refer to the subject set against my name in the printed programme (which I have only just seen)—"Trade Unionism of the Future"—and would point out that, when I received the invitation to be one of the speakers at this Symposium, I understood that my subject would be "Post-War Reconstruction Problems from a Trade Unionist point of view," and I prepared my notes accordingly. I hope therefore that the Chairman will allow me to proceed on those lines and not tie me down too rigidly to the title on the programme.

At the outset, I would emphasize that Trade Unionism is very much interested in post-war problems; it is vitally

interested in the war itself and has shown in no unmistakable fashion—not only in Britain, but in the Dominions and the Allied countries—its desire to see the War carried through to a successful conclusion, in the total defeat of Fascism and Nazism, and all that they stand for. Trade Unionism has already made great sacrifices, and will continue to do so, in the war effort. It is therefore vitally concerned not only in winning the War, but also in winning the Peace; and in the conditions which are likely to arise at the termination of the War.

I will go further than that: I maintain that the question of post-war reconstruction, the question of planning and definitely laying down provisions for dealing with the contingencies expected to arise at the end of the War, is *part* of the war effort. We must give our people something tangible to fight for, just as the Russian people have something to fight for, something to justify the great sacrifices they are making to-day.

But I want to emphasize that such planning must be done *now*, and proper provisions be so fixed that they cannot be ignored or evaded by the “powers that be” at the end of the war. Many of those present to-day are old enough to remember the last Great War, the promises that were made during that war—and which were never kept. We don’t want a repetition of that sort of thing, but unless the vested interests of High Finance and Big Business are removed from their dominating position in most of the countries concerned, unless the private-profit motive makes way for a saner and more humane economic system, there will be such a repetition. The New Order that so many people are talking of to-day will be just the same Old Order as before, and the war will have been fought in vain.

Trade unionists are, in fact, somewhat doubtful of the *bona fides* of some of those who are shouting so loudly to-day for an “all-in” war effort and are apparently so friendly towards Labour and the poorer elements of the community. In this respect I am reminded of the old tag, which I will paraphrase as follows:

“The Devil was sick; the Devil a Bolshie would be.
The Devil was well; the Devil a Bolshie was he!”

I agree with Dr. E. P. Phillips where in his Presidential address he speaks of the world of vested interests needing a shock, and in those words he indicates the real source of the world’s troubles to-day. Vested interests in Britain to-day, in fact, are preventing her from using her maximum resources in man-power and materials. Essential work is held up in

some cases, and many men are kept idle for long periods, because it does not *pay* the contractor concerned to do the work in a certain way. In a little pamphlet I have here, called "Labour Research," there is much information on that point. It also shows how, in spite of war, the banking system is making bigger profits than ever. What are known as the "Big Five" banks made an aggregate profit in 1941 of over 14 million pounds, equal to the boom year of 1929. In this connection I will read to you an extract from another pamphlet "After Victory—What?", which gives an item from the first prospectus of the Bank of England, issued in 1694,—"The Bank shall have interest on moneys which it shall create out of nothing"! (I think our worthy Chairman knows something about that!) That is the essence of the Money Power, which is permitted to use the nation's credit (the ability of its people by their labour power and natural resources to produce) for private gain, and which, with Big Business, exercises such a momentous influence on most governments. It was Big Business in Britain which in the pre-war years helped to build-up the mighty military machine in Germany that we are fighting to-day. It was Big Business (Dutch, American and Australian) which continued to supply Japan with war necessities almost up to the very moment of the Pearl Harbour attack. Why? Because it was the means of profit to some individuals.

With regard to the Banking System, listen to this from the "United States Bankers' Magazine," on August 26th, 1924 (in the depths of the depression which followed the last war):

"Capital must protect itself in every possible manner by combination and legislation. Debts must be collected, bonds and mortgages must be foreclosed as rapidly as possible. When, through a process of law, the common people lose their homes, they will become more docile and more easily governed through the influence of the strong arm of government, applied by a central power of wealth under control of leading financiers. This truth is well known among our principal men now engaged in forming an imperialism of capital to govern the world."

Also this from the "Economist," the British financial newspaper:

"At a time when the nation struggled almost at death's door for its very existence, and while masses of our manhood were daily being blown into bundles of bloody rags, British banking fraternities continued to create for themselves a great volume of new credit and to lend

that credit to us at interest, indeed, at progressively increased interest; no reference to the fact that this manufacture of bankers' credit some portion, variously estimated in amount, of what now stands as the public debt, was simply fabricated for private ends, and was not a *bona-fide* loan of real wealth to the nation. Professor Soddy has estimated that the bankers actually created £2,000,000,000, no less, of this bank credit, and lent it out to us at 5 per cent. That means £100,000,000 a year on nothing."

Also remember that some of the influential people connected with Banking and Big Business were just before the war connected with various organizations of a Fascist character; "Friends of Peace in Europe," "Anglo-German Fellowship," etc. This pamphlet ("After Victory—What?") mentions that the Anglo-German Fellowship included 28 members of the House of Commons, and 28 of the House of Lords, and gives the names of a large number of titled and prominent people who were associated with that organization. Some of those people were at the back of the Chamberlain Government when the Appeasement campaign was on. They didn't want war, but they wanted a state of affairs which would enable them to make profit by continuing to sell munitions to both sides. According to this pamphlet, the Bank of England sponsored a loan of £50 million to Germany early in 1939, and Montague Norman's comment thereon was:

"We will have to give Germany a loan of £50 millions. We may never be paid back, but it will be a less loss than the fall of Nazi-ism."

This pamphlet ("Labour Research") shows how "Heavy Industry," that is Big Business and High Finance, controls production in Great Britain, that the control of the various elements of production is in the hands of men closely associated with the control of the big private concerns engaged in such classes of business. This is what the "Economist" has to say on that point:

"The wartime necessities of the community and the peacetime interests of specific industries are frequently in conflict. It is in the community's interest that many sorts of industrial capacity should be increased as rapidly as possible: it is in industry's peacetime interest that capacity should be kept in close relation to normal demand. It is in the community's interest that all unnecessary consumption of scarce materials should be promptly and drastically restricted; it is in industry's interest to leave normal channels of trade intact as long as possible."

This is what the "Financial News" said on 27th March, 1942:

" In any event the heavy industries of the United Kingdom are now financially armed as never before."

And listen to the London " Times " of the 4th March, 1942:

" Britain . . . is to-day the only important country which allows monopoly to flourish without restriction. The present war, like the last, has again fostered the tendency towards combination. War requires rationalisation to the utmost. Rationalisation means concentration of units and reduction of competition. Moreover, the Government is in need of the assistance of association. Since the war began their power has in many cases acquired the veneer of semi-officialdom."

Some may ask what has this to do with Post War Reconstruction in South Africa, but my point is that it will be impossible to achieve any real improvement in the conditions of the mass of the people in any country while the system which permits of the Money Power control to which I have drawn attention persists. Unless that system is swept away and replaced by a system which regards the needs of common humanity as paramount, which does not tolerate the profiteer and the usurer, there is no hope for a better order, either in South Africa or anywhere else. A drastic change is necessary, and unless drastic steps are taken and definite plans of reconstruction, both political and economic, are laid down, the trade unionist feels that the common people will be "dished" after this war, just as they were after the last.

According to the " Star " of the 20th June, this is what our Chairman said the other day at a meeting:

" People were realising that the things they were fighting for were not fully realised in their own country. Many were attracted by new orders and by Socialism; they wanted a change after the war. He expected substantial changes after the war, but that did not mean they should introduce a new order; they could make the changes within the democratic system."

I agree with him that the necessary changes can be made within the democratic system. What is wanted is *real* Democracy, not the sham which masquerades as such in many countries to-day. We hear a lot of the Atlantic Charter, of the Four Freedoms, of Freedom from Want, the most important of all to millions to-day. Let us implement that

Charter and make it possible to bring about that Freedom from Want. That cannot be done until the private-profit motive and the system which permits the few to prosper at the expense of the many is abolished. If that is done, the better order that all mankind is earnestly looking for—and fighting for—to-day has a chance of achievement.

(7) POST-WAR RECONSTRUCTION AND NATIVE POLICY

BY

MARGARET BALLINGER.

The issue of post-war reconstruction will, no doubt, have been defined long before this point in this symposium; nevertheless I feel I must state it as I see it, at least in general terms, before I can attempt to present my conception of the place of the African therein, particularly with the brevity dictated by the tyranny of time.

My conception of the issue of post-war reconstruction is the obligation upon us to build the sort of society we keep saying we are fighting for and that we believe in as both desirable and possible, a society which will give first of all material security to all its members within the limits of its resources, that will then give to all a share in the well-being that these resources make possible, and that finally will give these things on the foundation of a freedom which will recognise the right of each to develop the highest and best that is in him, that will grant to all to think, to say and to do what seems best to them with due recognition of similar rights on the part of others and of the stability and well-being of society as a whole. Whether such a society can be realised within the framework dictated by the economic principles which govern our present organisation is open to question; but it is probably common ground among us that a much greater approximation to such a society can be achieved within these principles than has so far been attempted, and that it is to this approximation, at least, to which our protestations have committed us.

Now the intention and the will to attempt even this approximation, if sincere and intelligent, must, I maintain, presuppose the will and the intention to face a complete revision of the traditional Native policy of the country since under that policy as it now operates, none of the attributes of our desired society exists or can exist for Africans. I recently heard a naturalised German speak of this country

as the freest country in the world. That freedom does not extend to the African. He is governed by laws in the making of which he has practically no say—the terms of the Representation of Natives Act necessitate no essential modification of this statement. Under these laws, in many parts of the country, he may not worship as he wishes. If he cannot obtain recognition from the Government of the sect which he considers reflects his conception of how God should be worshipped, he cannot have a church, and he may not make his own house a regular place of meeting for worship. He cannot express his thoughts and feelings about his temporal existence save within the very strict limits of the Riotous Assemblies Act which functions much more effectively than many of us here are in a position to know and appreciate. In a country the economic and social structure of which is built on property, he may not buy land in any urban area, and in the rural areas, he may buy only in those circumscribed areas laid down by the Land Acts of 1913 and 1936. Outside these areas, he may not even lease land except on a labour tenancy basis, while in towns, his only leasing is in municipal locations on the terms and during the good will of the municipal authorities.

This exclusion from property in the narrow sense automatically reduces the economic value to the African of that property which still remains to him, his labour, by denying him an alternative to wage-earning. But absence of such an alternative—other than starving, of course—is not the only handicap under which the African suffers who would barter his labour in return for a livelihood. There are now few towns in the Union which he may enter to seek work, entry being dependent on an already agreed contract of service. But in any case, movement from one province to another, i.e. from one labour area to another, and in some instances within the provinces and within the towns of the province is governed, regulated and curtailed for Africans by the need to produce travelling passes which it is within the power of the public authorities to refuse; and finally what opportunities remain to him of selling his labour against his need to live are restricted not so much by legislative exclusion of Africans from industrial conciliation machinery and by the operation of Masters and Servants Acts as by industrial colour bars, explicit in mining, implicit throughout the whole of the rest of the industrial field. The effect of this implicit colour bar may be judged from the reaction of the employer who, on being asked how much unskilled labour he used, turned to his foreman with the question "How many Kaffirs have we got?" Where only one rung of the industrial ladder is open, the possible results of collective bargaining are likely to be very limited indeed.

And the social characteristics of the community whose economic opportunities are thus hedged round with exclusions? These are what reason would lead us to expect. The African people form a thick layer on the bottom of our economic and social structure, a layer essentially unstable because essentially without security. With few exceptions, the African people of South Africa live either on or under the bare subsistence line, those who are on that line being constantly menaced with the danger of joining those who have already fallen below it.

Poverty is the inevitable result of a policy which denies people property rights and rights of collective bargaining and industrial advance in a capitalist society. Nor can even the most enterprising individual do much to help himself where education does not open doors to opportunity and thrift cannot lay the foundation of investment against future need, against the storms of life, accident, sickness, old age. Thus poverty and insecurity go hand in hand. Nor is this insecurity eased for the African by the provision for him of those social services by which the state has increasingly sought to temper the winds of adversity for other sections of the community. Old Age Pensions, and Disability grants are not for him, and pauper relief still amounts to no more than pauper rations that lend themselves to Dickensian pillorying—a little mealie meal, a little fat, a little salt. Industrial accident and industrially acquired disease still give no continuing security even to the victim himself since our laws governing compensation in these cases still deny to the African worker the pension rights already long-established under political pressure, for other groups in the community.

I have drawn the lines of the picture very boldly, but those who know the situation at first hand will agree that the effect is no exaggeration of the truth. Indeed, added detail would but serve to heighten it—the destructive influence on rural family life of the constant flux of workers between country and town necessary to keep the reserve economy afloat even on its present low level of life, and on the town family of the need of both parents to work to keep the family alive at all; the alarming growth of juvenile vagrancy and delinquency, as great a problem of the countryside as of the town, the obvious fruit of lack of educational opportunity and still more of opportunity for the educated; and over all, the enormous sense of frustration that has been steadily spreading over a people who must see the delectable fruits of civilisation but may not share them.

But the failure of South Africa to provide any reasonable, let alone any good society for its African population is increasingly recognised and shamefacedly admitted. The question now is, what would the will to create a good society

for Africans involve. It would involve, in essence, an entirely new approach to the African himself, an approach which would regard him as an end in himself and not as the condition and background of the lives of others. That would in its turn necessitate ultimately two major changes in our law and in our practice. First of all, it would mean the removal of positive bars to his economic and social advancement, which would mean the removal both of legislative exclusions from property rights and of those exclusions, whether legislative or merely customary which now deprive him of the use of skill and intelligence. Explicitly stated, this would mean the repudiation of the principle of the Land Acts to make possible access to and the independent use of land in areas outside reserves by that large section of the people who are to-day entirely debarred from these privileges. It would also mean the repudiation of the principles of the Urban Areas Act and the recognition of the African in the towns as an essential part of town life, having the same rights and the same responsibilities as other sections of the community, to be established, governed and controlled as are other sections of the community. It would also mean the recognition of the African worker as a worker, with the right to use and invest his abilities wherever these can carry him.

With such changes in our law and practice, the African would lose the positive shackles which now not merely hamper but actually prevent his advance toward security and well-being. But these changes alone would not guarantee any certain arrival at these desired goals—indeed they would amount to nothing more than the liberal policy of 100 years ago with its illusion of freedom—a freedom to sink in the torrent of industrial advancement if you cannot learn to swim in time to save yourself. More, much more is needed if the African is really to achieve that progress and well-being to which the democrat claims every man to be entitled regardless of the pigmentation of his skin.

This "move" is a positive encouragement and assistance to progress and advance—first and foremost education, academic education to train the mind, but also practical education on farm and in workshop so that he may learn efficiency by practical experience; and then the encouragement of the use of skill and intelligence in agriculture, trade and industry; the development of the reserves so that they may become the homes of a real peasantry with a reasonable standard of comfort that will remove their necessity to flock into the towns as periodic wage-earners depressing the standards of

the town worker, the encouragement of those outside reserves who wish to farm, on the only conditions on which encouragement should be given to anybody, that is intelligent and efficient use of land; in both country and town, initiation into the mysteries of trade; and in the towns, an open door to talent to all levels of industrial occupation. And finally the extension to the unfortunates of this group of the assistances which we have increasingly provided, under pressure of need, for other groups in the community.

In other words, the complete reversal of our established policy and practice not only to allow but to encourage African development in all directions. Stated thus baldly, it sounds revolutionary. Actually it is not as revolutionary as it sounds, except in mental attitude. Already we are travelling along this road, slowly and somewhat painfully and grudgingly but none the less surely. Already a good deal of this revolution is actually in progress. For example. municipalities, having first achieved the complete administrative control of their African population as birds of passage or domesticated animals to be penned so long as they are wanted in our midst and ejected from the town when no longer in demand, have begun to discover that this population really consists of human beings without whom the town cannot survive, who, if they have no rights in the towns, have no rights anywhere, and whose ill-being reacts on the community itself; and in recognition of all these facts, we are getting the twofold move towards the establishment of property rights in the towns and of rights of representation on Municipal Councils the mere mention of which, a few years ago, would have raised a storm of protest which I do not anticipate for my own proposition to-day. In the industrial field, where discrimination has been most deeply entrenched to protect the vested interests of European workers, the barriers are also beginning to fall—very slowly indeed, almost imperceptibly, but they are falling. Where apprenticeship still guards the door to skilled occupations, no breach has, indeed, been made in the wall, and generally speaking, where the Industrial Council still holds the fort, work done by Africans is still “unskilled” work; but where mass production methods have successfully rendered the old apprenticeship obsolete, and the business of classifying jobs according to the degree of skill involved in their performance falls to the Wage Board, the defences of racial exclusiveness are beginning to be shaken and the African to get some recognition of the skill which ability and opportunity allow him to acquire. The beginnings of encouraged development in the reserves points in the same direction, as does the increasing support for educational opportunity for Africans on the ground that an ignorant man is an inefficient man.

These developments, it is true, do not represent any conscious or intentional change in the line of our accepted policy. They are merely an accommodation to experience. And as a matter of fact, we could have gone much further and much faster along this path even within the framework of our discriminatory policy—and indeed we would have done so, if we had been true to our promise. We promised that, when separation should have been achieved, Africans would not only be allowed but encouraged to serve themselves in their own areas—in these areas at least to do what in so-called European areas was to be done by Europeans. How have we kept that promise which held the possibility of very considerable advance for the Africans? The answer is, I expect, familiar to all of us here. To-day Africans in all our large towns, and in most of our small ones, live in houses built and maintained by European labour (recently the Minister of Labour refused to allow Africans to build schools in locations with funds derived from the poll-tax), and in large numbers of towns and villages, trading licences, though they may not now be given to non-Africans in urban locations, are refused altogether as likely to interfere with the livelihood of the European traders outside. The administrative services in native areas are themselves conspicuously slow to provide opportunities for Africans while Europeans crowd those services. Change these practices, which the most elementary justice demands, and even without that conscious reversal of the segregation policy which is bound to come, as General Smuts really foreshadowed in those now famous remarks of his in the City Hall at Cape Town early this year, and the African would be set firmly on the road to security and well-being. The weakness, however, of our not facing now the ultimate necessity for a conscious change of policy is that what is conceded tends to lack direction, and, much more important in my opinion, to lack generosity. Only so much is given as is wrung from us by economic pressure and necessity; and that is likely to go on being the case so long as our practice and our theory are pulling against one another as they are doing increasingly with the progress of our industrialisation.

Of course we shall be asked, not here I believe, but outside, what is to happen to the Europeans of our community if we are to embark on this reversal of our Native policy and take to encouraging and assisting African progress. I think in this stage of our national development, and with the experience of the last 50 years behind us we are entitled to counter with another question—

“What is to happen to us if we don’t.”

For fifty years we have endeavoured to build a secure and prosperous European community on the foundation of cheap

Native labour—for that is really what our segregation policy meant, and that only. Will anyone to-day say that we have succeeded when four out of every ten Europeans who reach the age of 60 are dependent on the Old Age Pension for existence and the costs of our Social Welfare Department are rising by leaps and bounds?

(8) RETURNED SOLDIERS AND POST-WAR RECONSTRUCTION

BY

S. D. MENTZ.

I would like to address you in an unofficial capacity, and, in doing so, I do not claim the concurrence of any Government Department or organised body.

The war has now been in progress for nearly three years and a great number of men have been returned from military service. Actually two distinct problems have to be faced, viz., the men already discharged and those who will be discharged during the war and at the time of general demobilisation.

During the first years of war some men who became ineligible for further military service were discharged without employment and it is this question that I wish to touch upon first because many of them are still unemployed and find it extremely difficult to sustain life under present conditions.

Generally speaking, these men can be grouped as follows:

- (1) Those who gave up good positions and who became physically and/or mentally unfit during their term of military service and could not, upon discharge, resume their former positions.
- (2) Those who occupied minor positions in civilian life and who rose to responsible rank in the Army.
- (3) Those who were unemployed at the time of attestation.

In private enterprise employers rightly demand service at all times and in all circumstances. Successful placement into employment must, therefore, be gauged on a standard of efficiency, knowledge, experience and general suitability to perform a particular service. This means that a worker must be able to maintain his position on a competitive basis whatever that position may be because while it is the duty of a placement officer to do everything possible to secure a

suitable position for a worker, the worker must justify himself in that position through his own efforts and service.'

Practical vocational guidance is essential; this entails careful investigation into each individual case before any attempt at placement is possible. The unit system must, therefore, be followed, and I venture to state that mass treatment cannot, and will not, produce successful results.

The Civil Re-employment Board under the Chairmanship of the Hon. Major v. d. Byl has done, and is doing, intensive research for the ultimate rehabilitation of returned soldiers. While the major schemes will no doubt apply to the greater numbers at the time of general demobilisation, unemployment amongst large numbers of discharged soldiers is a very real problem at the moment. These men are becoming despondent and they may well be forgiven for making unkind remarks. Usually one hears "We are no longer wanted, just like the last war. Nobody cares—promises are so much hot air," etc., etc. A very excellent leading article on the "Soldier's Home-coming" appeared in the "Rand Daily Mail" recently. This article amply portrays the work, aims and objects of the Civil Re-employment Board and is worthy of careful study.

The War Measure which ensures at least six months continuous employment with an employer where prior permission was given to attest, is sound in principle. This obligation has been honoured by most employers and it certainly eases the general position. It must be accepted, however, that all firms may not be in a position to fulfil their obligations for reasons quite outside their control.

It was an excellent gesture to set up dispersal depôts and the regulation whereby no soldier may be discharged without definite employment, is a sound measure, but, unfortunately, it was published too late to save the position entirely.

Employment committees, under the direction of the Department of Labour, have been set up in the larger centres of the Union. These committees include leading representatives of other Government Departments, commerce, industry, the mines, municipalities, health authorities and other important interests, and while these committees are doing excellent work, their concerted efforts have not, as yet, succeeded in placing all the returned soldiers.

Some of the reasons for failure are:—

- (a) A superior complex on the part of the man to do the job which he is really fit to do; (this attitude is psychological and can be easily appreciated, for having worn a uniform, occupied a position of authority and reckoning on the various promises made by the authorities, this man is

loath to revert to an inconspicuous and sometimes insignificant form of employment, e.g., former labourers on irrigation, municipal and other schemes had risen to the rank of sergeant, staff-sergeant and even higher, but it does not necessarily follow that a good soldier is a good civilian worker and vice versa).

- (b) Prior to enlistment many men were work-shy and even unemployable, but they were drawn by the glamour of a uniform and the adventures of war. Now, however, they find themselves once more on a competitive labour market in their former state. During service they enjoyed all the privileges of the Army and the ample allowances paid to dependants were in many cases the determining factor for enlistment, e.g., a man may have earned say 6/- per working day in private life, and upon enlistment as a private—presuming he had a wife and five minor children—his earnings in the Army would have amounted to approximately 20/- a day. During his term of service the family not only enjoyed a higher status, but also a very considerably increased income. Upon discharge this family must naturally revert to the man's former standard of living as determined by his earning capacity. In many cases the reversion is too great and a general state of discontentment is the inevitable result.
- (c) An argument constantly heard is: "If I were able and willing to serve my country, why should I be thrown back on my own resources now that my health has been ruined." The country owes a debt to the returned soldier and I am of the opinion that the authorities should not wait until the time of general demobilisation for the bringing into effect of schemes for rehabilitation. I wish to argue that each individual case should be dealt with expeditiously as it occurs and that all men who have been discharged and who are in need of employment or assistance should be contacted immediately, so that their individual cases may be dealt with; not on a competitive labour basis, but sympathetically and with such assistance as may seem reasonable in the circumstances disclosed.

The Civil Re-employment Board has been actively engaged on the various aspects of rehabilitation for some considerable time. I do not think, therefore, that it would be competent for me to suggest definite schemes, but I do wish to enumerate some of the types that will need employment and re-adjustment at the time of general demobilisation:

- (a) The young person whose educational, trade or professional training was interrupted.

- (b) The emergency workers in T, Q, S.A.A.F. and various other services, whose qualifications will be insufficient to entitle them to membership or a trade union.
- (c) Farmers who sold out prior to enlistment.
- (d) Men of good educational qualifications, but with no definite trade, profession or calling.
- (e) The usual "white collar" brigade with fair educational qualifications but no definite calling.
- (f) Men with no educational qualifications, trade, or calling—usually labourers or handymen—in private life.
- (g) Any of the above types who have to be adjusted to new work because of physical and/or mental unfitness.
- (h) Those who never worked before attestation and are not likely to work unless forced to do so.
- (i) Those who are totally unfit for any form of employment.

The position of the females will also present many difficulties. Women have entered "man's sphere of work" to a greater extent and they have proved themselves capable and reliable; it is doubtful, therefore, if they will readily revert to domestic life in the true sense.

The returned Coloured and Native soldier will also add additional problems. These will need very special attention.

The war is costing an enormous sum of money, but every right-thinking citizen will readily realise the necessity for this expense. It is pleasing to note that the Central Authority has set up machinery for dealing with post-war reconstruction and rehabilitation on a large scale. While the cost of destruction is tremendous, the cost of building up must, of necessity, be equally large if it is to be effective. A wide vision is essential and everything possible should be done to honour the undertakings given to the men and women who are sacrificing their very lives for the principles of democracy and freedom.

(9) EDUCATION AND POST-WAR RECONSTRUCTION

BY

PROFESSOR L. F. MAINGARD.

University of the Witwatersrand, Johannesburg.

I shall not speak to you as a Professor of Education, which I am not, but as an educationist—as one who has been intimately connected with education, in various countries, for over a quarter of a century. I can only claim to be an observer who has had many varied experiences and many opportunities, both as a teacher and as an administrator, not only of getting into contact with my colleagues and the outside public, but also with the general body of students, and of gauging trends of opinion in many directions.

You will not, therefore, expect me, in the course of this short address, to roll out statistics or tire you with technical details about education. My endeavour will be, in accordance with the general plan of this symposium, to discuss broad policies and fundamental principles. I shall try to place before you a statement of our present difficulties and of our most pressing problems which should be considered in a general scheme of reconstruction.

One of these fundamental principles, which will guide us in our survey and indeed will dominate it, is that a country's educational system must be integrated into the social system of that country. For a nation can be adequately served by its citizens only if its education provides the proper training of its youth to fit them for the higher purposes for which it stands. The English educational system is a case in point. The ecclesiastical dominance in education during the Middle Ages found fitting instruments in the "cathedral school" and its later development the "grammar school" and the Universities of Oxford and Cambridge. But by the end of the eighteenth century the level had sunk very low.

A revival came about the middle of the nineteenth century with Dr. Arnold. That great reformer found chaos at Rugby and out of it he fashioned the great "public school" spirit. Self-discipline and self-government, embodied in the institution of the "prefect" system, sport and the classics all centred round the building of "character." The Universities—Oxford more especially than Cambridge—followed suit in concentrating on general culture and the historical and literary approach. The finished product furnished the type of the English leaders, excellent administrators and Empire builders who admirably served the colonial and commercial expansion of the nineteenth century. And let it be noted

that these changes and adaptations were the unconscious work of private initiative, not the conscious effort of a central administration.

Indeed it was not until 1899, more than a quarter of a century after the Magna Charta of English Education, the Act of 1870, that the Board of Education was created. Education spread to the "masses"—as the phrase once was. The primary school, the secondary school and the modern universities came into being. But the Universities are autonomous in a large measure, and the schools are left to their Local Authorities. The Board of Education adopts a policy of non-intervention, or at most, one of benevolent control through the allocation of its grants and its Inspectorate.

Perhaps I have gone into greater detail than I should over this question, but my object was to give a practical example of the integration of an educational system in a wider social system, and to show how perfectly English education at the different stages of its evolution reflected the needs of the community.

The continental educational ideals are very different. The State keeps a tight hand on it and the Universities are institutions in which science and scholarship are highly specialized and pursued for their own sake. Nor is there any stress laid on the social side of the student's life, or on general culture. This latter aspect is well and successfully cared for in the schools, in which, however, there is no place for the formation of character in the English sense of the term.

Here in this country our educational system grew out of influences, English and Scottish. The old University of the Cape of Good Hope was modelled on the old University of London, and our present-day universities have had to a large extent as patterns of organisation the modern English and Scottish universities. Here too we have our "public" schools—Bishops, St. Andrews and others, which are still active. We also have our Government schools, strictly controlled by the Provincial Administrations. But some aspects of the continental ideas are coming into some of our universities, especially since the custom has sprung up for some of their graduates to go to continental places of learning instead of to England or Scotland, as the bulk of them used to do in the past.

So we see many agencies at work and this is intensified by the warring ideals to which the country is being subjected. There is no singleness of purpose but many opposing forces, often each pulling its own way. The present position cannot better be summed up than in the words of the Prime Minister

at the Inauguration of the Social and Economic Planning Council: "Our human society is stratified in various racial and cultural layers and there is more and more a feeling of strain and tension." What he described as applying to the general situation is reflected in our educational world.

These circumstances make it extremely difficult to formulate a general scheme that will suit the situation. But in any case, in building for the future, these facts will have to be given their due share of consideration.

After these general remarks, I shall now proceed to put before you what I consider some of our most pressing problems. I do not claim that the list is exhaustive. Other educationists in other universities or schools may have had other problems apart from these, claiming their attention.

BILINGUALISM.

This is one of the most crucial and controversial subjects of South African education. A state of bilingualism is no new thing in the history of the world. In conquered countries, invaders and invaded mix and speak each other's language, as a matter of necessity or expediency. The descendants of the Germanic invaders of the Roman Empire, in the early years of the Middle Ages, were, according to linguistic evidence, definitely bilingual. In modern times, a country like the United States, with its large immigrant population, has important bilingual groups—the descendants of these immigrants, Italo-American, Germano-American, etc. In other countries like Switzerland, Belgium or Canada, there are two or three official languages.

Here in South Africa the position is different from that of those countries. It is the aim of our national policy that everybody should become bilingual, and in order to make a success of life, one has in fact to be bilingual, especially if one wishes to become a Civil Servant or to enter certain callings or professions. Now, there are different degrees of proficiency in bilingualism and whether an individual is bilingual or not depends on our definition of the word. There are only a few specially gifted individuals who can lay claim to perfect bilingualism. But for a large number of people, to speak two languages is a difficult and laborious process.

The two official languages are taught in our schools. As I understand it, at any rate in some schools, the second language is treated as a "foreign" language, i.e., it is book knowledge, without the realities of a living language. The fact, of which linguists are well aware, is not always appreciated, that it is not at the school or the university that a "foreign" language is learnt fully. The best they can hope to do is to lay a foundation—good or bad—according to the teacher and the taught. The only real way of fully

acquiring a modern living language is by the two groups of speakers mixing together.

Hence most universities abroad insist that the student shall spend a term in the country of the language of his choice. Hence also, in this country, the deterioration of the power of expression. (I am speaking of the experience of my colleagues and myself.) Hence also, in private letters, official correspondence, and even in the English versions of some important Government Reports, extraordinary samples of English language and English style occur. This is a very serious handicap, especially when we remember that the eloquence of leaders in all ages has made them what they are.

I do not think that our system of single medium schools is an ideal one; not only from the point of view of the mere acquisition of language. There is a graver issue at stake. The single medium school is widening the breach between the different sections of our population. Thoughtful critics like Professor Haarhoff, of the University of the Witwatersrand, and, more recently, Professor Grant, of Cape Town, have spoken or written eloquently and convincingly on this subject. Within my own experience, at our own University, we have always encouraged and welcomed Afrikaans-speaking students; in many cases their mixing with other types of students has taught them to appreciate each other's point of view.

I therefore wholeheartedly agree with the principle of the dual medium school.

PASSAGE FROM SCHOOL TO UNIVERSITY. It is not every school boy or every school girl who can or will enter the University. The financial obstacle which may close the door to the University should be removed in a well-balanced educational system by means of a liberal measure of bursaries and scholarships. Poverty should never be a disqualification to a promising boy or girl.

The more serious disability is the insufficient mental level of the child. There are, unfortunately for themselves, and for the institution they join, many intellectual misfits in our Universities. There are students who have "scraped" through matriculation. Others, in spite of their success, are mentally immature. These and other causes make the first year at the University, in many cases, a school year. This is an unsatisfactory state of things.

I do not blame the schools or the standard of the leaving examination. Whether we should have a post-matriculation class, as suggested by some competent authorities, or whether we can devise some better method of examination should be a matter for further investigation. Some measure of relief was granted by an Act of Parliament (1941) introduced by

the Minister, which gives powers to the Universities to require certain specified subjects or standards for definite faculties. It is a step in the right direction, but it is not enough.

EXAMINATIONS AND OVERCROWDED LECTURE ROOMS.

Reverting to examinations, a system which allows concentration on a few days for the testing of a whole year's work and possibly rewards the successful crammer, is not a perfect one. More use should be made of oral tests and more weight attached, under strictly controlled conditions, to the class work of the year. Most observant and impartial teachers—the two conditions are essential—could say long before the date of the examination which candidates should pass and which should fail.

There is also a tendency to over-examination in Universities and possibly also in schools. In universities this may be due to the large numbers with which some of our Departments are overburdened. In such a case that may be the only way of knowing the performance of the students. Another evil consequence of overcrowding is that one of the essentials of University education, individual contact between teacher and taught, is impracticable. I believe the position is also bad in the schools.

The remedy applied by the Universities is that of limitation of numbers in certain departments or faculties. The remedy is a rough and ready one and may prove to be inadequate, as the nation's needs may demand a larger supply of certain types of specialists. I suggest that a more satisfactory method would be for the Government or some other competent authority to have an investigation into the numbers wanted and for the Government to finance the institution adequately for students in excess of the limited number.

VOCATIONAL EDUCATION.

The recommendations of the third interim Report of the Industrial and Agricultural Requirements Commission and the plan outlined by the broad vision and wise statesmanship of the Prime Minister at the inaugural meeting of the Social and Economic Advisory Council, foreshadow an intensification of our industrial development after the war. More and more trained workers and technicians will be required to implement this policy. But we have an excellent framework already existing which only waits to be further enlarged.

The foundations of our technical education have been well and truly laid by such able organisers as Professor John

Orr. Its very recent developments to meet the increased demand of our mechanised war have been very far reaching. We need have no fears for the future.

In our Universities, too, a greater demand for specialized technical training is to be expected. But more should be taught to our technical students than further specialization. If they are to take their place as leaders of industry, something more will be required of them.

THE PROBLEM OF OVER SPECIALIZATION AND ITS CONSEQUENCES.

This is an age of specialists. The present trend, in fact, is in favour of greater and greater specialization. Yet there are dangers inherent in over-specialization, however imperative it may be to-day. We see them in our present day education.

The specialist is so absorbed in the pursuit of his own branch of knowledge that he often forgets or cannot see that there are other branches of human activity in which he should be interested or about which he should know something. The high wall with which his speciality surrounds him obscures his view and limits it. As if to increase the misunderstanding, we speak of the different departments of science and learning as "subjects," as if science and learning could be conveniently divided up into unrelated units. Life knows of no watertight compartments. Ignorance of other "subjects" leads to contempt, indifference or a shyness to attempt to look beyond our immediate ken, a dangerous mental habit and a disastrous one, if it is allowed to dominate its victim in after life. The remedy, to my mind, lies in general culture, which is merely in its essence a training of minds in the direction of a general and intelligent interest in the larger problems of life, of securing the means of understanding them and attempting to solve them. Humanistic studies—I use the term here in the widest possible sense, as covering the study of man in his various social contexts—have the virtue of a broadening outlook and the power of lifting the mind out of the rut of routine. Specialization is essential, but never more than to-day has the necessity been created for wise comprehension and broad vision in handling our present day difficulties and ensuring a better organisation of our society.

Some of the leading universities in America have realised the implications of narrow specialization and insist on the general culture of the B.A. or B.Sc. degree as a prerequisite to entrance into a professional school. Here in our own university, the professional faculties have felt the need of a widening of the outlook of their students—the Faculty of Medicine have even tried to work out a scheme including some

of the more cultural subjects in their curriculum. The Faculty of Law actually solved the problem by insisting on a first degree as a condition of entrance.

Other competent authorities have suggested a modified form of the Oxford "Modern Greats" or the inclusion of part of it in the professional syllabus. But these are technical matters which would carry us beyond our present purpose.

One other material point—the importance of the spirit of independent criticism, which we usually associate with research in our universities. Yet in our eagerness to acquire facts for our specialities, it is not infrequent that we neglect it in our teaching. Yet it is this habit of constant questioning which has conditioned the progress of the world. Its absence or non-existence is very often closely bound up with that attitude of indifference or unwillingness to shoulder responsibilities to which we have already referred. Its counterpart elsewhere is largely responsible for the surrender of power into the hands of dictators or undesirable governments.

In the period of transition which will follow and in which we can expect government control, which already regulates so much of the details of our daily life, to be intensified, well-informed interest and independent criticism will be more valuable than ever. Therefore, the best means for securing the proper balance between over-specialisation and the acquisition of an adequate background of general information and, in the second place, the development and encouragement of independent thought and judgment are among the most important questions to be considered, when we think of the future.

PRIMARY AND SECONDARY SCHOOLS.

I have tried to touch upon some of the most essential topics of our South African education. Many things have had to be left unsaid, in the short pace of time allotted to me. I have devoted a good deal of attention to the University. Let me, then, add that the primary and secondary schools are and will remain the educational backbone of the country. For the few thousands who come to the Universities, many tens of thousands will, for various reasons, never see the inside of a University lecture-room or laboratory.

It is in the primary and secondary schools that the teachers have the chance of influencing the great bulk of our population and that influence will condition the later mental development and the future behaviour of our citizens in life. We, in the Universities, depend on their work, and our teaching will be retarded or advanced accordingly. Two more points should be stressed. We can envisage in them powerful agents which will be entrusted, in a growing

measure, with the care of the nation's physical fitness, for it is at this youthful stage that scientific training will produce its maximum results for good. They, too, will increasingly become centres for the beneficent work of social welfare, more especially in the sphere of nutrition. Already we have free meals and the free distribution of milk for the poorer elements of our population. These two insistent questions of nutrition and physical fitness, among many others, must loom large among the extended functions of our future schools.

Note: In the course of the discussion on this paper, the point was raised about what was called, if my recollection is correct, the complete omission of any reference to the Bantu position. As I had no opportunity, because of lack of time, of answering this criticism, I would like to make the following remarks.

My paper, as will be seen, is concerned with general policies and trends of education. I have been at pains to show the importance of the principle that the educational system of a country should be integrated in its social and political system. I would have thought that these critics would have deduced that the position of the Bantu was implied in my review, especially as I quoted the reference made by the Prime Minister to our racial difficulties and that I arrived at the conclusion that they would have to be taken into consideration, when the time comes.

I, in common with many others, believe that the extension of Bantu education in this country is a *political* and not an *educational* question. I agree that a much larger measure of financial assistance should be secured for this purpose. But this can only be effected by State action.

What I have said of our general educational problems applies to the Bantu also. They, too, want more vocational education; they, too, will have eventually to face over-specialisation. The question of examination, nutrition and physical fitness in schools are as important to them as to us. I can see no *educational* reason why they should be treated differently. In fact, I think it is unsound to create sectional points of view, when discussing the whole question on a scientific and objective basis.

Lastly, I would again emphasise in a slightly different form, that the question of more schools and more teachers and more higher education in their case is a matter for the State and the Legislature, as expressing the will of the nation, which is another way of stating the principle of the integration of the educational system in the social and political systems.

(10) POSITION OF SOCIAL SERVICES IN A POST-WAR RECONSTRUCTION PROGRAMME

BY

G. A. C. KUSCHKE.

Secretary for Social Welfare.

The main heading on to-day's agenda is post-war reconstruction. A large portion of the field has already been covered by previous speakers. Where and how social services fit in remains to be examined. The discussion of this problem would be facilitated if a huge circle could be visualized and sub-divided into three sectors in the ratio 7:2:1 for accommodating our black, white and brown population respectively. All persons able to support themselves under all circumstances should be placed nearest the centre of this circle; those less able to do so should be placed a little farther away from the centre and so on until the perimeter would be occupied by permanently dependent persons. Any number of concentric circles could now be described to delimit varying degrees of economic status. For simplicity's sake three concentric circles would suffice: persons safeguarded against all contingencies of life occupying the innermost circle, those only moderately safeguarded the inner, and dependent persons the outer fringe.

In point of fact there is nothing static about the groups traced against this broad background. Some citizens are continuously moving towards the centre whilst others are moving in the opposite direction. Movement towards the centre is synonymous with improving personal welfare, whilst movement away from the centre means retrogression.

When commerce and industry flourish, the inner circle expands, causing the width of the middle belt and of the outer fringe to decrease proportionately. Industry and agriculture—the two activities mentioned by our programme—have it in them to enlarge the surface area of the inner circle and the middle zone, thereby providing more persons with opportunities for self-support. The Department of Social Welfare on the other hand has three complementary functions to fulfil: firstly to prevent individuals irrespective of their station from becoming maladjusted; secondly to rehabilitate; and finally to provide maintenance for those incapable of rehabilitation.

Welfare in its wider sense may therefore be compared to a centipede moving forward on many legs only one of which is "Social Welfare" or "Social Services." Stated differently, it means that personal welfare arises from a variety of causes such as individual temperament, competence, education, opportunities for remunerative employment,

accidents, strikes, Black Fridays, droughts, floods, and the international situation. Various techniques in the hands of different agencies have been evolved for meeting such varied conditions.

In the performance of the three-fold task of prevention, rehabilitation and maintenance, the following departments are involved: Social Welfare, Public Health, Education, Agriculture, Labour, Railways and Harbours Administration, Provincial Administrations and Municipalities, besides a host of voluntary agencies. The type of assistance rendered varies in accordance with the social symptoms requiring treatment. In the social workers' tool kit one finds the following: old age pensions, blind pensions, war pensions, invalidity grants, poor relief grants, clubs for boys and girls, social centres, work centres for women, work colonies for won't works, hostels for low-paid workers, settlements for the aged and the unfit, settlements for the semi-fit, flower farms for epileptics, drink addicts and hoboes, hostels for delinquents, reformatories, opportunity schools, institutions for children in need of care, maintenance grants for children, crèches for children of working mothers, nutrition schemes, the Youth Training Brigade, and last but not least, the Physical Training Battalion, which although stationed at Voortrekkerhoogte and run by the Military, is financed by the Department of Social Welfare. Although the list is not exhaustive it gives some idea of the machinery at the disposal of social workers in the Union. If pins could be placed on the colour disc referred to previously, each pin representing the above services wherever they occur, the pins would be found to bunch in the small white sector. That gives food for thought and indicates the direction in which action should be taken.

Broadly speaking social workers fall into two categories, viz., Government officials and voluntary workers. The main task of both is the rendering of social services which entail the contacting of individuals, and through personal influence, advice and help removing causes of worry and inconvenience and generally creating conditions that will make for the happiness of the individuals concerned.

The importance of the co-operation between Government Departments and voluntary agencies cannot be overrated. In the Department of Social Welfare we have found it so, and so has the Department of Defence which is getting magnificent assistance from many voluntary workers, professional, commercial, industrial, labour, insurance and others drawn from all walks of life. It would be a pity if war fund and liaison committees representing as they do complete cross-sections of the community were allowed to lapse after the war. If possible these committees should be geared into the ordinary social welfare machinery before it

is too late, so that their experience and service will not be lost to the community on the cessation of hostilities. A comparison of the work now being done by peace-time voluntary agencies with that of war fund committees, reveals a high common denominator, viz., the rendering of personal services in respect of finance, health, education, personal problems, employment and legal matters. In regard to legal matters I would like to remark that every citizen theoretically has the right of access to the courts to protect himself and to obtain justice. In practice, however, many individuals are debarred from availing themselves of this right because of the lack of money. The purpose of legal aid is (i) to supplement the "pro deo" and "in forma pauperis" procedure allowed in law, and (ii), to arrive at an amicable settlement without litigation. It should require no stressing that a "Poor Man's Lawyer" service organised on a national basis is required in the Union now. Naturally the need for such a service will be much greater after demobilisation.

When that will come about or what the world will look like when it does happen, nobody knows. At the present moment victory or defeat is the issue that overshadows all others and requires the concentration of all energies. Nevertheless to skimp social services now would be a mistake. Experience gained during the last three years by my Department and the Department of Defence proves that social services rendered with understanding and sympathy by persons of character and standing are essential during periods of national and personal crisis. The post-war period will be such a one imposing great strain on civilians, demobilized volunteers and their dependants, on commerce, industry and on the Government. It is therefore indicated that comprehensive schemes for bridging the gap in employment between the end of the war and the re-establishment of peace-time industrial conditions need to be supplemented by extended and improved social welfare services. The rationalisation of the distribution of welfare services amongst Government Departments, the Provincial Administrations and Municipalities should form a necessary preliminary to grading up cognate pension schemes to a liberal uniform level. An extension of staff will be another post-war requirement. Closer co-operation with war funds is already desirable. This idea—I trust—will appeal to war fund committees and lead to appropriate action.

In conclusion I would offer three brief observations. firstly: the Union's racial texture is so closely interwoven economically that the welfare of any one section cannot be achieved by the neglect of another. Secondly: prevention is better than cure. The vexed problem of under consumption

particularly of foodstuffs will have to be tackled. My final and closing remark is, that all combatant nations have been living at an emotional fever heat since September, 1939. It would, therefore, not be surprising if we were to be emotionally exhausted after the war. Hence progressive anti-depression policies in the economic and the social welfare field should be adopted now whilst the spirit of service is upon us.

(11) DEVELOPMENT OF OUR HUMAN RESOURCES

BY

DR. E. H. CLUVER,

Director, South African Institute for Medical Research.

EVIDENCE OF DEFECTIVENESS OF OUR HUMAN RESOURCES.

Infant Mortality.

Adult Morbidity and Mortality.

Low Physical Efficiency.

REMEDIES.

Nutrition.

Housing.

Physical Education.

Vaccination.

Reorganisation of Medical Services.

CONCLUSION.

For the fourth year in succession, I am confronting the Annual Meeting of the Association with evidence of the socially and economically unsatisfactory state of the most important of our resources, the human population.

In 1939 at East London under the Chairmanship of the Hon. J. H. Hofmeyr I contributed to a symposium on our human resources, and came to the reluctant conclusion that most of the persons born in the Union live a precarious life of low value to the State chiefly because of preventable mal-nutrition and insanitation during infancy and childhood. At the 1940 Meeting in Johannesburg Dr. E. Jokl and I analysed physical performance data collected from a very wide survey of school children of the various races—European, Bantu, Coloured, Indian and Chinese. These children had been subjected to tests of physical endurance, skill and strength. Our finding was that there was an impressive discrepancy between the efficiency potential and the actual standard of performance of the population. The human material was not inherently, biologically bad but required development.

Last year I utilised my presidential address to Section D to introduce a symposium on Research in Physical Education. I pointed out that in time of peace a population brought to

the maximum degree of physical fitness might have at its disposal potential human labour far in excess of its industrial needs; the satisfactory employment of leisure would become a matter of social importance. In war time there could be no question of superfluous labour potential. All human labour not needed in the industrial organisation must be made available for the military machine. We were in this war and we had to win it. Our adversaries whose morals we deplore had advanced far beyond us in organising man power. We could admire their scientific achievement without in any way condoning their deplorable morals.

To-day I propose after briefly reviewing the evidence of the defectiveness of our human resources to discuss the urgently needed remedies.

We in South Africa are as yet making very poor uses of our human resources. We have allowed them to degenerate and in large measure to become not an asset but a liability to the country. Let us then review the evidence of this:— the high mortality rate from preventable causes; the increasing cost of the care of the sick and the loss of their services to the State; the low physical (and therefore economic) efficiency of most of the remainder.

EVIDENCE OF DEFECTIVENESS OF OUR HUMAN RESOURCES.

INFANT MORTALITY.

We lose annually close on three thousand of the European babies born in the Union before they are twelve months old. Conditions are slowly improving; the number was 3,250 in 1919 and 2,725 in 1930; the death rate per 1,000 births fell during those two decades from 82 to 50. There is little cause for congratulation in that. It is still a deplorably high rate and compares very unfavourably with that of many other civilized countries where the rate is calculated for the whole population and not as with us for the favoured upper European section of society only. We have managed to maintain some rags of self-respect in this matter by refusing to collect vital statistics of our Bantu population.

Infant mortality is very largely preventible. It is almost entirely due to underfeeding (in particular to an inadequate milk supply) and other hygienic neglect. The rate could be reduced to a negligible figure by proper diet and medical and nursing supervision. For obvious reasons it is highest among the very poor, particularly of the non-European population. Unfortunately, it is not even true, as sometimes suggested, that infantile ailments pick out the unfit for destruction. Those who survive the evil tests of malnutrition and insanitation are permanently weakened and most liable to become imperfect citizens, a liability rather than an asset to the State.

ADULT MORBIDITY AND MORTALITY.

Our infant death rate is capable of very great reduction. But the sickness and deaths which occur after childhood are also largely preventable. Very few people as yet die as a result of true physiological senility.

Our maternal mortality rate continues to be shockingly high. The improvement in twenty years even among the favoured European population is tragically small. It dropped from 4.9 per 1,000 births in 1921 to 3.4 in 1940 in spite of the potent new weapon we possess in the sulphonamide group of drugs. We can ill spare these mothers of our future citizens. To stop this large number of deaths in child-bed we need more and adequately trained doctors and nurses.

Obviously preventable diseases like typhoid and diphtheria continue to take a heavy toll of life and health. Tuberculosis is actually on the increase among our non-European population, an inevitable result of increasing malnutrition. Attempting to combat this evil by increased hospitalisation, at present a very vocal demand, is but a costly confession of failure of our social organization.

LOW PHYSICAL EFFICIENCY.

High death and sickness rates are apparent indications of deficiencies in our manpower. Less easily measurable is the physical and therefore economic deficiency in our industrial workers who are pronounced "clinically" fit. Though suffering from no manifest ill-health for which they would be rejected by labour recruiting agencies they may yet be unable to obtain or retain employment even in times when there is great demand for labour. Thus during the unprecedented economic expansion that occurred during the industrial boom period of 1935-36 we had 120,000 unemployed Europeans. Out of our immense non-European reservoir of some eight millions we are unable to recruit the 400,000 labourers required by our mining industry. The Union can only supply half this number; the remainder come from outside its borders, chiefly from Portuguese territories.

The methods introduced into this country by Dr. Jokl have made a scientific examination of the degrees of physical inefficiency among various groups of the population possible. The methods and results of these investigations have already been reported to the Association and other bodies. May I briefly recapitulate these findings. The analysis of 20,000 tests carried out on school children of our different races revealed—(a) that the physical potentialities of the various races was strikingly similar, and, (b) that for the bulk of our school population the actual level of physical efficiency was much below its potential level. Their ultimate labour value would, therefore, be very low unless steps were taken to combat this preventable state of affairs.

Dr. Jokl studied the effect of an hour's physical training a day on the 2,500 trainees who participated in the Technical Training Scheme of the Witwatersrand Technical College during the first two years of the scheme. He found that the allotment of working places alone did not solve the problem of transforming unemployed or unemployable young men into efficient and successful workers. Before the daily period of physical training was introduced the standards of discipline and working efficiency in the shops were very low. The introduction of physical training led rapidly to improvement; the number of days missed because of minor ailments decreased; discipline in the shops improved strikingly; the daily output of work showed a conspicuous increase. The trainees at first disliked the exercises and some degree of compulsion was necessary. Later they showed positive enthusiasm and there were requests for an increase in the physical education periods.

We examined also a section of the population specially selected because of a high physical standard, viz., recruits for the Police Force. The men in training at the Pretoria West Police Depot showed striking improvement as the result of physical education, in spite of their initial fitness. At the end of the course there was an increase in body weight, chest circumference and in bulk of calf and upper arm muscles.

The most convincing evidence of the low actual and high potential physical efficiency of South African youth was supplied by our study of the results produced in the Special Service Battalion. That experiment by the State demonstrated that by a relatively small public expenditure the physical efficiency of largely unemployable young men could be raised so that they become valuable citizens. We set out to collect facts regarding the biological basis of human labour, the fundamental element in the production of individual and commercial wealth. Assuming that physical working capacity is the primary determinator of the economic value of the citizen we came to the valuable conclusion that through physical training virtually every man and woman in the country could be developed to a level of economic maturity.

The young men in this Battalion had been unemployed, and their posture, general bearing and nutrition were poor. They were given good living conditions, strict discipline and three hours physical training a day. The aim of the course—physical, economic and social rehabilitation—was attained in the great majority of cases. Over 90% of these were placed in suitable employment at the end of the course. Their physical, physiological and psychological improvement was demonstrated by appropriate tests carried out before and at intervals during the course.

This investigation aroused very wide interest. The Journal of the American Medical Association compared our

experiment with American C.C.C. activities. The American Journal of Public Health was impressed by our finding that the low initial standard of efficiency was not due to a basic biologic defect, but that it was largely the expression of environmental shortcomings; it suggested that national planners might well ponder over these results, war or no war. The Canadian Medical Association Journal remarked that there were few experiments on this scale in which the results both mental and physical had been so carefully followed up. The Lancet in a lengthy editorial commented on the ample evidence adduced—from improvement in height, weight, general physique, and athletic capacity, employment and subsequent career—of full economic rehabilitation. The Journal of Physical Education and School Hygiene (Glasgow) considered that the whole investigation was “of first class importance and of the highest interest to all who care for the well-being of the young.” The Medical Journal of Australia stated that the investigation was “of great importance in regard to the Empire’s war effort.” Similar views were expressed in many other journals in various countries.

REMEDIES.

NUTRITION. The thinking public generally has now become acutely aware of the need for a change in the dietary habits of the great bulk of the population. Living on starch to the virtual exclusion of most of the protective foods must result in weak, ailing and economically unsatisfactory people. Man cannot live by bread alone, not even Government bread; nor by mealie meal porridge. Yet it is just that preponderant section of our population which has to earn its living by its manual efforts that is compelled to subsist on this mal-nutritious diet. I have repeatedly stressed the necessity for providing a diet balanced by the protective substances: Milk and milk-products, eggs, fruit, vegetables and meat, if we wish to avoid increasingly costly hospitalisation and to produce economically satisfactory and contented workers.

Starch foods, which have not been deliberately deprived of their small content of vitamins and minerals, must continue to form the bulk of the diet of our manual workers, if only because of their cheapness and high energy value. But a daily intake of protective foods must be insisted on. To make this possible a complete re-orientation of our farming policy is necessary. Not only must we produce vastly more food on the farms, but the relative proportion of crops must be altered. For larger crops better farming methods are needed. Irrigation and anti-soil erosion projects must be developed to an extent hitherto unthought of; the tractor

must replace the ox for ploughing; and generally modern scientific methods must be introduced.

Protective food production must be stimulated by every possible means and increasingly replace the thought-stunting mealie production. Farmers have latterly been demonstrating for themselves that in many parts of the country the raising of protective food crops is considerably more lucrative than cereal crops. An irrigated morgen under tomatoes yielded many times the return of the same area previously under mealies.

Details of the re-orientation scheme will have to be worked out with adequate technical guidance by a beneficent Government which is acutely aware of the needs of the consumer as well as those of the farmer. No export of food is yet justified by the state of development of our agricultural industry. But it does not follow that the farmer will not get adequate return for his labours. A policy of internal consumption of our farm products, subsidised if necessary, will repay the country to an extent hitherto unimagined, by reduction in hospitalisation costs and by a vast increase in our fit industrial manpower.

HOUSING.

Our Government has made a commendable gesture in the provision of funds for its economic and sub-economic housing scheme. But we have still a very long way to go before the bulk of our workers, European and non-European, have those environmental conditions which are necessary for the maintenance of good health, prevention of disease and the promotion of the physical efficiency necessary for the highest industrial productivity.

We have some ghastly mistakes to correct. Chief among these is the herding of hundreds of thousands of young male Natives in mine compounds away from their families. The segregation policy now has few supporters and none amongst those who have studied its social implications. The high cost of venereal disease alone to the State justifies the abolition of the compound system. It is the cost not only of the treatment, inadequate as it is, of the sufferers, but of the inefficient and lost labour of the victims and their potential offspring.

If the industries which are being planned for the future are to get the best value from the employees, provision will have to be made for *homes*, not barracks, where the workers can enjoy normal family life. Our mining industry, too, will have to depart from the policy of indentured Native labour. Its life is not so ephemeral as to justify imposing so unnatural a mode of living on the bulk of its employees. Nor does any thinking man still have fears as to the consequence of settling large numbers of Bantus permanently on

the Witwatersrand. Many medical and social evils will disappear with the mine compound, and there will be a great saving of the country's material wealth.

PHYSICAL EDUCATION.

I trust I have been able to convince you by my brief summary of the investigations on the physical efficiency of our people of the vast supply of man-power which now lies unexploited. A mighty army, black and white, is at present economically unemployable not because of inherent biologic inefficiency but because of remediable factors. It has been amply demonstrated that provided this army is properly fed and housed and has its minor ailments corrected it can, by accepted methods of physical education, if necessary compulsorily applied, be brought to a condition of employability.

It is no longer necessary to stress the fact that physical education exerts effects which are primarily formative or educational; that the morphological and functional adjustments which take place in the organism as the result of training all tend to increase the performance capacity of the human organism, producing a marked improvement of working efficiency. But we have as yet made little attempt to apply this knowledge. Only one of our Universities yet has a Department of Physical Education. Such a department will have to become a most important section of every one of our Universities and University Colleges. It should exert its influence on the whole student body producing normal or optimal physical fitness in all and not only in that relatively small section which at present reaches the competitive sports teams. It should turn out large numbers of scientifically trained teachers able to take charge of physical instruction in our schools and factories, and, at any rate for a while, in post-school labour camps.

Our one "labour camp," the Special Training Battalion, has demonstrated its value. Until our schools turn out physically satisfactory persons school life will have to be extended to allow of service in a labour camp where the necessary rehabilitation process can be carried out: elimination of preventible minor defects such as dental caries and flat feet; proper nutrition; and physical training. We can with confidence embark on such a policy since we have conclusive evidence that our "industrially unfit" young men and women are so because of inexpensively remediable causes.

VACCINATION.

Medical science has made possible the direct protection of individuals against many diseases to which they would otherwise be susceptible. Vaccination against disease must be looked upon as an interim measure pending the raising

of the social and economic status of the population. Most of these diseases, in particular the filth diseases such as typhoid and typhus would automatically disappear when satisfactory living conditions including proper sanitation are provided for all. Meanwhile we have in vaccination a weapon for combating many of the diseases which take a heavy toll of life and health in the Union. Much propaganda is still needed to educate the public up to this fact. Little headway has as yet been made and here again some measure of compulsion may initially be needed in the interest of the general welfare.

Diphtheria makes heavy inroads on our child life; a large proportion of those who recover are permanently damaged. It appears to have been on the increase during recent years. The annual notifications exceed 3,000; the number of actual cases is undoubtedly very much higher owing to our system of notification being still very defective. Anti-diphtheria vaccination is now a relatively simply procedure involving two or three injections with very little unpleasantness and conferring virtually complete protection against infection. In certain areas in America the disease appears to have been completely abolished by this means. With the assistance of the Government, local authorities can now offer free immunization to the population. Yet in spite of the ravages of this disease the response on the part of the public continues to be so poor that it has been variously suggested that immunization of our child population against diphtheria infection should be made compulsory by law.

Typhoid fever, owing to the low economic status of the majority of our population and the insanitary conditions under which they are compelled to live, continues to be responsible for thousands of cases of serious disease in the Union every year. Pending the removal of these conditions, threatened populations can be completely protected by means of vaccination. The introduction of typhoid endotoxoid has made the process all but painless with very rarely any unpleasant reactions. The absence of typhoid among our troops in the North is the direct result of systematic vaccination of all.

Lice are responsible for the periodic ravages of typhus in our Native territories and constitute a serious ever-present menace to our unskilled labour force. Civilization to the level of regular usage of soap and water will permanently remove the danger. Meanwhile we have been able to cultivate the causal rickettsiae in the laboratory and a vaccine to protect the masses threatened is now available.

Plague is endemic amongst our wild rodents. From them it spreads every year to a certain number of human beings in rural areas. Until our towns are built entirely on modern

rodent-proof lines their inhabitants continue to be in serious danger. Dr. Grasset has succeeded in perfecting a very effective live avirulent vaccine. It affords protection after only one injection. Threatened populations can now be adequately protected as is already being done in one war zone.

We have no yellow fever infection in the Union as yet, but the mosquito vector of this disease is widely distributed among us. If infection should be introduced here, for example, as the result of troop movements from infected North African areas, we have a vaccine with which to combat it effectively. The Government has come to an arrangement with the South African Institute for Medical Research for the production of this vaccine on a large scale.

Influenza, which among post-war malnourished people suffering from severe stresses, is liable to assume pandemic proportions, is still a cause of anxiety. But the causative organism has now been successfully isolated and cultivated in many countries. It should not now be long before we also have a satisfactory counteracting vaccine for this serious disease.

But let me repeat that vaccination against most diseases must be looked upon as an interim measure pending the advent of the brave new world in which malnutrition and insanitation shall have disappeared.

REORGANISATION OF MEDICAL SERVICES.

Our medical services as at present constituted are of relatively little value in conserving our human resources. Although the number of names on the medical register has increased to over 3,000, we are witnessing a rapid increase of diseases, such as tuberculosis, among our non-European population and an increasingly urgent demand for costly hospitalization, and that in an age which has witnessed phenomenal advances in medical science. The reason is that the bulk of the profession is required in the present social order to earn its living by curative work. It has little or no part in the application of the measures which modern medical science has made available for preventing disease and promoting positive health.

The only satisfactory solution will be for the introduction of salaried medical services in which the members are not compelled to exploit ill-health to make a living. In such a service competition will be replaced by co-operation and there will be every inducement to apply preventive measures. Meanwhile our medical schools will have to prepare for such a service by a re-orientation of the training they provide. The emphasis will have to be less on diagnosis and treatment and much more on causation and prevention. The scant attention at present paid to nutrition, physical education and

social measures generally will require radical change. The doctor of the future will have to be an integral part of the social organisation and not stand largely outside it as he does at present, waiting to deal only with the results of its inefficient functioning.

CONCLUSION.

We have the evidence of the degeneration of our population. Preventive disease is playing havoc among the under-privileged. Our investigations on manpower have provided us with overwhelming evidence not only of the low level of physical efficiency but of the possibility of developing it to a high level. The country is awakening to these facts, stimulated by a devastating war. We are becoming nutrition-minded; in the medical profession there is a strong movement for reorganization on preventive lines. The Industrial Development Corporation has set up a Manpower Research Department. These are greatly encouraging signs. But we shall have to proceed at a greatly accelerated rate if we are to win the peace which we hope is now not too far distant.

(12) SUMMARY OF CONCLUSIONS

BY

THE HON. J. H. HOFMEYR,

We shall, I think, all agree that we have had a most interesting day, that the papers and discussions have been of a highly stimulating character, and that the value of the scientific approach to our subject has been amply demonstrated. In Dr. van Eck's words, we can claim that we have to-day been seeking to "think dynamically in terms of rapidly changing world conditions."

According to the programme I must now proceed to give you a summary of our conclusions. As no conclusions have been formally arrived at, that is a task of some difficulty. At best I can but seek to present a picture of the range of the discussion. And in doing so, I can enter into details. I too must adhere to the brevity which is dictated by the tyranny of time.

This, however, I should make clear in advance. It is my duty to reflect the views that have been expressed here. It is not for me to state my personal opinions. What I have to do is to seek to reflect the trend taken by a discussion in which I have not participated.

We have covered a wide range. Superficially indeed there has been a mass of conflicting interests. But as Dr. Berliner remarked this morning, the diversification of science is not contradictory but enriching. I think we have all been conscious of that fact. In part at least that has been so because we have never been able to get very far away from the human factor. It came out when Dr. van der Byl was speaking to us of the industrial aspects, and in doing so brought home to us the growing humanisation of industry. It came out again during Professor Leppan's contribution on Agriculture. During the afternoon we were almost entirely occupied with it. I could not help recalling the old Latin tag, that even if you seek to drive out the human factor with a pitchfork, it will always come back on you.

I do not think I should go any further without stressing a point which, although it was emphasised in General Smuts's introductory message, has received all too little attention during the day. I refer to the necessity of remembering, in our consideration of post-war reconstruction of South Africa, the fact that we are part of a wider world. South Africa cannot isolate itself. It cannot do so in its industrial policy, nor in its agricultural policy, nor yet in health matters or social policy generally. You cannot in these days build Utopia in a single country. You must take world conditions into account. We are all part of one great inter-related world. The war has brought that home to us—but it will be no less applicable when peace is restored to us.

Without wishing to be critical, I feel that I should draw attention to an omission from the programme of this Symposium. Our consideration of the problem has not been complete in so far as the importance of the mining industry has not been dealt with, it has indeed only been referred to in passing. And yet it is of fundamental importance. I could not help, when I listened to-day to speakers advocating reforms of all kinds, which however desirable they are, are none the less costly—I could not help asking myself just how practicable those proposals would be if America were to stop buying our gold. Personally I have no fear that that will happen, but one has merely to mention the possibility, to bring home the point that gold mining is not a stable and assured industry. We have to-day considered agriculture and secondary industries and the part they must play in the future as the props of our economic fabric. But mining is still that main prop to-day. The essence of our economic problem always seems to me to be that it is in the nature of a twofold race against time. On the one side it is a matter of expediting the time when agriculture and industry can more fully take the strain than they do to-day; on the other side it is a matter of extending the time during

which mining can play a predominant part in carrying the burden. That means that a great deal of consideration will have to be given to special problems of mining at great depth; it means also that the question of our post-war taxation policy in relation to the productivity and the further development of the industry will need careful consideration.

I pass on to deal more specifically with what has been said here to-day. First I would like, if I may, to revert to something which I said this morning, namely that if the average level of well-being is to go up, the amount of production must increase. That indeed was perhaps the main finding of the Industrial and Agricultural Requirements Commission. The crux is increased productivity. I need not emphasise the value of the contributions of Dr. van Eck and Dr. van der Byl in connection with the Industrial aspects. But I feel that I should repair one omission in my own introductory remarks. I spoke of the destructiveness of war, of the handicap under which we shall start in post-war reconstruction in that we shall first have to repair war's ravages. I should have gone on to say that, though war is essentially destructive, it does also stimulate industrial efficiency. One thinks naturally in this connection of Dr. van der Byl's own achievements in the organisation of our war-time industry in South Africa. We can confidently expect that some of the benefits will endure after the war. In referring to what had been done, Dr. van der Byl paid a tribute to the skill of our engineers. To that I would add, as I am sure he meant to add, the adaptability of our workers. The advances made in industrial efficiency will undoubtedly be of great value to us as we tackle the tasks of peace.

What are the things that we must chiefly keep in view in relation to our industrial development? First perhaps one should mention clarity as to our aims, which Dr. van Eck so rightly stressed, and here of course considerations of world policy are of great importance. Then there is the matter of improved organisation in the use of our labour forces. To some extent we still suffer in our industrial organisation from the old fallacy that because certain types of our labour are cheap, they need not be used economically or efficiently. We shall have to get away from that. Then there is the necessity of more effective exploitation of our resources of raw material. Finally there was emphasised this morning the need to make better use of our manpower. Dr. Jokl said quite rightly that manpower is the most important of all raw materials. Undoubtedly the factors which make for the employability of individual workers and potential workers can be stimulated. It is here that the humanisation of industry becomes so significant. Dr. v. d. Byl in this connection spoke of the importance of a vigorous policy to

improve the physical condition of workers, of the necessity for better housing. Here I would emphasise the valuable contribution that engineers and architects can make by cheapening the cost of housing schemes without any sacrifice of essential amenities, and would refer in passing to what has been done along these lines at Port Elizabeth, where so important a lead in housing enterprise has been given to the cities and towns of South Africa.

It is right too that I should remind you of what Dr. Freed said about the necessity of normalising the social life of the Bantu worker. The compound system has done much damage to native family life. We should do all we can to keep that damage at least within bounds.

There was the further point made by Dr. van der Byl, when he referred to the desert of unfairness from which the unskilled and semi-skilled workers at present suffer. He raised a difficult question when he did so, but it will have to be faced, and that can best be done in co-operation with Trade Union leaders.

I pass on now to the Agricultural aspects as presented to us by Professor Leppan. Despite the obvious differences between the industrial and agricultural aspects, the general desiderata are in the two cases broadly the same. We need, in the matter of agricultural policy also, as Professor Leppan pointed out, clarity as to our aims. What he said to us about Denmark in that connection was very much to the point. Already we have suffered heavily in the matter of the productivity of our soils for lack of such clarity in the past. We need better planning and organisation of agriculture in its economic aspects. We need also an improvement in labour conditions. Professor Phillips stressed the necessity of agricultural labour being better trained, better housed, and better fed. It was well said—but don't let us forget that the general economic position of agriculture in South Africa is such that it is by no means easy for all our farmers to progress very far along those lines. Though such improvements are to the ultimate advantage of agriculture, they represent only part of the problem. Don't let us forget that the immediate scientific and economic problems of South African agriculture are very difficult—that they cannot be solved by the waving of a wand. It is of course desirable, as Dr. du Toit said, that we should make it productive and attractive to remain on the land. Perhaps his remarks and those of certain other speakers suggested to the audience, that if only the scientists had their way, those aims would easily be attained. I could not help reminding myself that there is no Government department which has been so well-served with scientific and economic advice as has the Department of Agriculture or of Public Health, and I have derived

some consolation from the thought, that our lack of success in dealing with these matters is perhaps not entirely due to the lack of capacity of the politicians.

And so we passed on to the social aspects. May I here again remind you of something which I said this morning. I emphasised the point that we can't go back to the *status quo* after the war, even if we would. It is that which perhaps more than anything else has been emphasised by the trend of the day's discussions.

Mr. Downes quoted Ambassador Winant's statement about the necessity of a great social offensive to crush economic evils. Undoubtedly there is a growing strength of public opinion in this regard. Mrs. Ballinger urged the necessity for the complete revision of our traditional native policy.

One of the good things which the war has been doing for us has been to arouse in us a sense of our imperfections as a community. We are fighting for democracy, for freedom and security, for human dignity and human decency, but it is being brought home to us that these very things for which we are fighting are very inadequately realised in our own land. Our democracy is an incomplete democracy—some sections of the community have no political representation at all, while others are only partially represented. We are free as a nation from foreign domination, we enjoy as citizens, speaking broadly, freedom of speech, and thought, and worship, but nearly all our non-Europeans and many of our Europeans have not got that freedom from want which is based on economic security. And there is not much human dignity and human decency in the slums of our cities or even in some of our rural areas.

How are these things to be altered? There will no doubt be a difference of opinion as to whether a change of our political and economic system is essential or whether what is necessary can be achieved by the operation of our democratic machinery. Some will agree with Mr. Downes as to the necessity for the removal of the profit motive. Others will not. Some will accept the view which I expressed the other day, and to which Mr. Downes referred, that you cannot make socialism work effectively as an economic system without the backing of dictatorship, and that in the long run dictatorship is always an evil thing—others perhaps will not. But I think we shall all be at one with the resolution that there must be no return to the *status quo* after the war, and I think we shall also all accept the necessity for the continuance at least for a period in time of peace of the measures of control which have had to be imposed upon us as a result of war-time conditions. In that connection may I repeat a very wise

remark made during the day that the continuance of control makes it essential to maintain both freedom to criticise and the ability to criticise.

In the same way, doubtless, we shall not all agree as to the extent to which we can go in the revision of our traditional native policy, though I believe we do all agree that in that regard we fall very far short of the ideals for which we are fighting. This is one of the instances where idealism must be tempered by realism. The question of how far public opinion is prepared to go is in this respect a very realistic consideration. To a great extent the matter is one for education and enlightenment. Happily there has been progress, marked perhaps by nothing so well as by General Smuts's epoch-making speech on the basis of trusteeship. I am glad that Mrs. Ballinger made reference to the fact that we are travelling, however grudgingly, along the right road. Undoubtedly that progress has in large measure been made possible by the work of Mrs. Ballinger herself and of others like her. But quite obviously we still have a long way to go.

One line of approach has been mentioned here to-day, the importance of which is not always fully realised. The question, Will it pay the Europeans to improve the standards of living of non-Europeans, is often well worth asking. Miss Hawarden rightly remarked that there are very many people with whom grounds of justice do not go so far as grounds of economic expediency, and it is just as well that we should take account of that fact. Idealists have not always realised that grounds of economic expediency often just have to be advanced to obtain the necessary public support—nor have they appreciated how strong those grounds sometimes are. I was impressed the other day by a remark made to me by the Mayor of Port Elizabeth, to the effect that the conservative members of his Council who had originally opposed the housing programme were now keen supporters of it, because they had satisfied themselves that it paid.

So much in general for the social aspects dealt with to-day. Let us now pass on to be more specific. Much of the discussion had as its centre the ineffectiveness of the utilisation of our human resources. In this respect we were on more than one occasion brought back to where we found ourselves at the East London Symposium of three years ago. Dr. Cluver produced striking evidence of our imperfections in these matters. He spoke of our high infant mortality rates, of adult morbidity and mortality, of low physical efficiency. Of course we have in all these respects been effecting improvements in recent years, but the improvements have not been rapid enough. I think, however, that it is only fair to make the point that the slowness of our progress has not necessarily been due to a lack of desire to advance,

but to a lack of knowledge of the correct methods to apply. The great value of the work of Dr. Cluver and those associated with him lies in the fact that as a result such knowledge is being obtained. But here also, we have a long way to go—and it is in respect of our non-European population that we fall farthest short in taking full advantage of our human resources.

We pass then to the question, how are we to make the most of our human resources, in relation to industry and to civic life.

Our consideration of that question to-day has fallen under three heads.

First, Education. The essential point is that we have good material—the achievements of our engineers and of our workers generally in the making of munitions at this time is a proof of that—but better use could be made of it. And that applies to non-Europeans no less than to Europeans. The educationist will have to apply himself to the task of providing the better training necessary for the work that lies ahead. In our ordinary primary and secondary schools more can be done than has yet been done to give the teaching a vocational bias without their being vocationalised. More use can and should be made of the background in the teaching of the ordinary stock school subjects. That is after all the underlying principle of the Bekker farm schools in the Transvaal. Then there will have to be further developments in technical education, and there one thinks not only of the Technical Colleges in the big towns but also of the vocational schools in the rural areas. Each type of school has a distinct purpose to serve. Our Universities also, without losing their character can set themselves to make the biggest possible contribution to the reconstruction problem.

Of course we must never forget the twofold function of education—to provide training both for life and for the making of a living. The central problem of education is indeed to strike a just balance between these two functions. Professor Maingard rightly emphasised the importance of general culture in our educational activity, and did well to remind us that citizenship is more than the earning of a living. It is on that account that the language question to which he referred—and I think we endorse his views in that regard—is of such great importance.

In the second place we dealt with Social Services. Here it has wisely been said, that the highest form of charity is that which makes charity unnecessary. Mr. Kuschke distinguished the three functions of Social Welfare activities. First in order must come prevention. Where despite efforts in that direction, evils come into being, rehabilitation must

be the aim. But even under the best possible conditions there will always be a residual problem necessitating maintenance.

We can view with some measure of satisfaction the improvements which have been made in the sphere of social services, but there is still much to be done, and in particular, there is a tremendous task awaiting us in relation to the non-Europeans. Mr. Kuschke very appropriately reminded us that "the Union's racial texture is so closely interwoven economically that the welfare of any one section cannot be achieved by the neglect of another." The strength of a chain is still that of the weakest link.

And then, thirdly, Dr. Cluver suggested some of the remedies to be sought within the sphere of health and physical education for the ills which he had diagnosed.

He spoke of nutrition in that connection. From what he said I think the point emerged that there are two great desiderata, the spread of education and information about nutrition—there are many people who have the means, but not the knowledge, to feed themselves and those dependent on them properly—and the making readily available of more of the right kind of food. Incidentally, one wonders if we are, as a result of the type of bread which we are now compelled to eat, going to have that improvement in the health of the nation which on the basis of scientific theory we were led to expect.

Dr. Cluver's remarks in this connection linked up with those of Professor Leppan. It is clear that to some extent at least our farming policy must be changed, if only so as to make it easier for the people to get enough of the right kind of food. In this regard of course there has been a change since we discussed these matters three years ago at the last Symposium. Dr. du Toit said that we must stop the export of food at a loss and produce more. The circumstances of our time have forced these things upon us. Since 1939 there has been a large decrease in the export of food-stuffs from South Africa. There has moreover, owing to military and civil requirements, been a large increase in the internal demand. As a result production is being stimulated to-day. The present circumstances will of course not last for ever; it should, however, be our aim to relate the production which they are stimulating with the permanent nutritional needs of the people.

Then Dr. Cluver spoke about Housing—and here his remarks are to be linked with those of Dr. v. d. Byl. I think I can say that our achievement in the matter of Housing is one of the best features of our social policy as a State. Only recently the amount available for commitment for sub-economic housing has been raised to £17,000,000.

Thirdly, there is the question of Physical training. Here too a good start has been made. A few years ago the Government set up the National Council of Physical Education, and valuable work is being done by that body. But here, too, it is largely a matter of making available the right information as to methods and procedure. In the past these matters have been neglected not for any lack of goodwill, but just because the necessary knowledge was not to be had. I need hardly remind this Association of the work that has been done to repair that lack in recent years.

Finally, Dr. Cluver spoke of the reorganisation of our medical services. May I say that the outstanding service which Dr. Cluver has rendered to South Africa in recent years has been his insistence on the necessity of shifting the emphasis in medical work from treatment to prevention. Already the idea is bearing fruit in University medical training, and I have no doubt that the Health Commission which the Government has undertaken to appoint will do a great deal to ensure a further advance along that road. It would seem, however, that there is still a task ahead of Dr. Cluver in the education of his own profession in this matter.

Enough has been said to-day to impress us all with the magnitude of the task of post-war reconstruction. We shall surely avoid the mistake of under-estimating the difficulties. Mr. Mentz's concrete examination of one specific aspect of that task—the problem of the returned soldier—will doubtless have brought that home to us. The immediate aspects of reconstruction work will certainly not be easy, and we must not forget the danger of emotional exhaustion after the war, to which Mr. Kuschke referred. There will be many types of people to consider. There is the worker who to-day is drawing big money for overtime, and will have to get back to normal. There is the munition worker who has been brought into industry because of the war, and whose job will come to an end when it is over. There is the soldier who may have lived on a higher standard in the Army than he did in civil life, and whose "wants have become needs," in Mr. Murray's phrase. There will be natives who have been given specialised training in the Army and will not be able to find scope for their new attainments. There will also, as Dr. Freed has pointed out, be many difficulties of personal readjustment.

These problems will of course have to be dealt with not in the mass, but in individual cases. The readjustment of the outlook of the individual will in many cases be difficult. It will depend on the help that is given to him, but much will also depend on the individual himself. A measure of discontent is of course inevitable.

The Government's task will of course be a costly one. No one realises better than I do its financial implications. If anyone thinks that we are going back to the *status quo* in the matter of taxation after the war he had better undeceive himself.

But however much the Government does, there will still be a residual problem. Mr. Kuschke rightly emphasised that there are many factors that make for human welfare. The ultimate problems are human problems, and this was brought out clearly in Mr. Mentz's reply to the discussion on his paper. Of course it would be all so much easier if we could just regiment the human beings with whom we have to deal! I sometimes think that the essence of the problem of reconstruction is the reconciliation of freedom and order. Order is the underlying principle of dictatorship. Every human being might become a perfectly-functioning automaton under such a system, but at what a cost! The basis of our society is happily *not* regimentation, and though it might be very much easier for the administrator if it were, we would lose tremendously in the matter of the essential human values for the attainment of which freedom is a necessary condition.

Let me close on this note. There is much that can be done by State action to secure a new and better world. A great obligation rests on those in positions of responsibility to create the conditions for a better life. But when all that can be done has been done, we are still left with the ultimate human problem. Do not forget that in addition to all the changes the desirability of which has been voiced here to-day, changes must also be wrought in individual men. One thinks of the dreams which men had during the last war—of a reconstituted society, of a new order. Mr. Downes spoke of that, as indeed I had also done in my introductory remarks. Those dreams only came true to a very small extent. That was not merely the fault of vested interests, of inadequacy of statesmanship, of emotional exhaustion. It was also due to the fact that there had been no re-birth in the spirit of man. That is a very important reason for the fact that after 1918 we had no real peace, only a shabby armistice from which we were plunged into a total war. Well, perhaps the very fact that this is a total war gives us ground for hope. Perhaps on that account we have more reason to look forward to a moral and spiritual re-birth. Whether that be so or not, the necessity of such a re-birth must be emphasised. We have talked much to-day of the necessity of changes. I close by reminding you of Tolstoy's words: "Everyone thinks of changing humanity, but very few think of changing themselves."

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